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16. ABSTRACT

Past attempts to assess the monetary impacts of ozone or other air pollutants on agriculture have had only sparse plant science information on which to base an assessment. This paper reports on an economic assessment of the effects of simulated changes in ambient ozone on U.S. agriculture using recent crop response data from the National Crop Loss Assessment Network (NCLAN). The economic analysis is limited to those ozone effects directly associated with production and conumption of a set of agricultural commodities. Effects on non-agricultural commodities and compliance costs of achieving the simulated changes in ozone are not evaluated here and hence, these economic estimates are not necessarily net economic effects. The results are derived from an economic analysis based on a U.S. agricultural sector model that includes major crop and livestock production as well as processing and export uses. The economic effects of four hypothetical ambient ozone levels are measured and compared with a 1980 base situation. The analysis indicates that the economic effects as measured in income-equivalents to producers and consumers of agricultural commodities of moderate (25 percent) ozone change below ambient levels are approximately \$1.7 to \$1.9 billion. A similar increase in ozone pollution results in costs (losses in income) of \$2.1 to \$2.4 billion. These economic estimates display varying sensitivity to the form of the response and meteorological data incorporated in the assessment.

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THE ECONOMIC EFFECTS OF
OZONE ON AGRICULTURE

Abstract

Past attempts to assess the monetary impacts of ozone or other air pollutants on agriculture have had only sparse plant science information on which to base an assessment. This paper reports on an economic assessment of the effects of simulated changes in ambient ozone on U.S. agriculture using recent crop response data from the National Crop Loss Assessment Network (NCLAN). The economic analysis is limited to those ozone effects directly associated with production and consumption of a set of agricultural commodities. Effects on non-agricultural commodities and compliance costs of achieving the simulated changes in ozone are not evaluated here and hence, these economic estimates are not necessarily net economic effects. The results are derived from an economic analysis based on a U.S. agricultural sector model that includes major crop and livestock production as well as processing and export uses. The economic effects of four hypothetical ambient ozone levels are measured and compared with a 1980 base situation. The analysis indicates that the economic effects as measured in income-equivalents to producers and consumers of agricultural commodities of moderate (25 percent) ozone change below ambient levels are approximately $1.7 to $1.9 billion. A similar increase in ozone pollution results in costs (losses in income) of $2.1 to $2.4 billion. These economic estimates display varying sensitivity to the form of the response and meteorological data incorporated in the assessment.

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TABLE OF CONTENTS

Page

I. Introduction 1

II. A Review of Assessment Issues and Past Studies 3

Biological and Practical Issues 4

Economic Issues 5

Assessment Methodologies Applied to Agriculture 7

A Review of Regional Assessments 8

A Review of National Assessments 14

III. Methodology 18

The Farm Model 20

Generation of Other State Activities and Crop Mixes 23

The Sector Model 23

IV. Procedure 28

V. The Data: Sources and Assumptions 32

Plant Response 32

Ozone Data 35

Moisture Stress - Ozone Interactions 42

VI. Results and Implications 47

Base Model Results 48

Analysis I 52

Analysis II 61

Analysis III 63

Page

Analysis IV 65

Analysis V 66

VII. Limitations of the Analysis 68

VIII. Summary 70

References 73

Appendix A: Analytics of the Assessment Model 81

Appendix B: Estimation of Acreage-Yield Response 98

Appendix C: General Crop Model and Moisture Stress 101

Appendix D: Yield Response and Ozone Data 103

LIST OF FIGURES

Figure

1 Structural Features of the Sector Model 26

2 Example Model Tableau 27

3 Regional Ozone Levels, by Year 41

4 The Effect of Moisture Stress 46

5 USDA Production Regions 53

LIST OF TABLES

Table

1 1981 Acreage and Value of Major U.S. Commodities 4

2 Summary of Regional Economic Assessments 9

3 Summary of National Economic Assessments 15

4 Primary Commodities in the Economic Model 22

Page

5 Secondary Commodities in the Economic Model.................. 28

6 Summary of Alternatives Assessment Analyses.................. 34

7 Weibull Model Response Function Estimates.................... 36-37

8 Seasonal Average Ozone Levels................................ 39-40

9 July Drought, Yield Reduction and Moisture Stress Factors..... 44-45

10 Actual and Model 1980 Prices and Quantities for Crops......... 49

11 Actual and Model 1980 Livestock Product Prices and Quantities. 51

12 Model and Actual 1980 Regional Cropped Acreage................ 54

13 The Economic Effects of Ozone: Analysis I.................... 56

14 Distribution of Consumer Surplus Between Domestic and Export Markets.. 59

15 Prices of Selected Feed Grain, Oil Seed and Livestock Commodities.. 60

16 Effect of Ozone on Regional Producer Surplus................. 62

17 The Economic Effects of Ozone: Analysis II................... 64

18 The Economic Effects of Ozone: Analysis III.................. 65

19 The Economic Effects of Ozone: Analysis IV................... 67

20 The Economic Effects of Ozone: Analysis V.................... 68

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EXECUTIVE SUMMARY
THE ECONOMIC EFFECTS OF OZONE ON AGRICULTURE

The harmful effects of ozone and other air pollutants on vegetation have been documented for at least 35 years (Middleton et al., 1950; Brisley and Jones, 1950; Bleasedale, 1952). Attempts to assess the monetary impact on agriculture soon followed the recognition of an ozone problem, motivated in part by the need for such information in the formation of environmental policy. Until recently however, attempts to measure the agricultural benefits of reduced ozone have been hampered by incomplete or even contradictory biological information. Where data did exist, the assessment procedures by which the economic estimates were generated were not always consistent with economic concepts.

The National Crop Loss Assessment Network (NCLAN) recently has attempted to improve on the state of knowledge in the area of crop response to air pollutants (Heck et al., 1982). The output from the NCLAN crop experiments are intended ultimately to form the basis for regulatory policy making and support economic assessments of the national consequences of ozone on agriculture. Performance of a preliminary economic assessment using these data is one objective of the NCLAN program. A final assessment using additional data from further NCLAN experiments is scheduled for 1986.

The purpose of this manuscript is to report on the preliminary NCLAN national economic assessment of ozone effects on agriculture. The economic analysis is limited to those ozone effects directly associated with the production and consumption of a set of agricultural commodities. Effects on non-agricultural commodities as well as compliance costs of achieving any changes in ambient ozone levels are not evaluated here, hence the estimates are not net economic effects. The analyses, data and results underlying this assessment represent the collective biological, meteorological and economic knowledge gained from the NCLAN program through 1983. The results are derived from an economic analysis based on a U.S. agricultural sector model (adapted from Chattin et al., 1983). Empirical emphasis is on six major crops (corn, soybeans, wheat, cotton, grain sorghum, and barley) which account for over 75 percent of U.S. cropped acreage (USDA, 1982). Potential ozone effects on hay are also evaluated using the average yield response of other crops as a surrogate. In addition, the assessment accounts for the derived-demand relationship between feed grains, such as corn, and livestock, by including a livestock production and feeding component.

The specific objectives of the analysis are:

1. to provide assessments of the economic consequences of alternative ambient ozone levels to agriculture, including those accruing to both producers and consumers of agricultural commodities;

2. to test the sensitivity of these economic estimates to varying yield forecasts reflecting sources of uncertainty within the NCLAN response data; and

3. to use these results to provide insight on the importance of improved information for possible inclusion in subsequent economic assessments of ozone effects on agriculture.

The analysis and methodology are conceptually similar to the numerous induced change analyses found in the agricultural economics literature. The assessment methodology for the case of ozone was implemented using both detailed farm-level models and a macro or sector model. The agricultural sector model component is a price-endogenous mathematical programming model of the agricultural sector, i.e., an activity analysis spatial equilibrium model (Takayama and Judge, 1971). Such sector models have been used extensively by agricultural economists to simulate the effect of alternative agricultural policies or technological change (Heady and Srivistava, 1975; Duloy and Norton, 1973). Among the various methodologies available to formulate policy models, mathematical programming has proven to be a particularly useful tool given its ability to predict potential consequences of as yet unrealized policies. This general methodology has been applied to air pollution effects in a number of recent regional studies; e.g., Adams et al., 1982; Adams and McCarl, 1984; Howitt et al., 1984; and Rowe et al., 1984.

Data for the sector model were provided in part by a series of farm models based on linear programming (LP) models and analyses of historical data which were used to model producer behavior. The LP-based farm models (REPFARM, McCarl, 1982b) were implemented for representative farms in the Corn Belt. For areas outside the Corn Belt, historical data were used to generate whole farm plans. Crop records by state for 1970-1981 were used to develop representative state level crop mixes and to derive econometrically estimates of crop yield changes when crop mix changes. These whole farm plans from both sources were then used to pregenerate a number of cropping activities for the sector model (originally developed by Baumes, 1978 and documented in Chattin et al., 1983) utilizing the USDA FEDS budgets. The economic model is thus a sector model using data generated by the farm models or historical data following the procedures in McCarl (1982).

The economic model uses alternative ozone-induced yield changes to estimate the economic effects due to ozone changes. Each of a series of hypothetical ozone scenarios is judged against a 1980 ambient ozone base solution. The difference between the base solution reflecting 1980 parameters and the hypothetical ozone analyses provides an estimate of the benefits or costs of the ozone change.

A plausible solution is established for a base case; then the model is solved using alternative yield values (modified from actual 1980 yields) that reflect hypothetical ozone levels in each production area (state or sub-state levels). The yield adjustments are derived by use of a mix of NCLAN response functions applied to the ozone levels. In this analysis four alternative ozone levels are evaluated which represent: 10, 25, and 40 percent reductions in ambient ozone concentrations and a 25 percent increase in ozone. The four ozone adjustments are applied to both 1980 and 1978-82 mean levels.

For some crops within the NCLAN data there are several cultivars (varieties) on which to base yield adjustments for use in the economic analysis. Screening of the multiple cultivar data for those crops indicates that a common or "pooled" response model estimated across cultivars is appropriate (Heck et al., 1984b). For other crops, only one or two cultivars are available in the NCLAN data. Specifically, pooled response models using multiple cultivars are available for corn, soybeans and wheat, with two cultivars of cotton (one irrigated or western cultivar and one nonirrigated or southern cultivar) and individual cultivars for grain sorghum and barley. Using different combinations of response functions drawn from this set, the four ozone alternatives are then translated into corresponding yield changes. The economic effects of the four yield change situations are evaluated by solving the economic model under each yield change.

Five distinct analyses are performed, each with the four alternative ozone levels. Analyses I and II use various combinations of pooled responses for certain crops in addition to the single cultivar crops. Analysis I uses pooled response functions estimated across data from statistically similar cultivars of each crop, while Analysis II is based on a pooling of cultivars grown in a given region. In the pooled analyses, a few cultivars are not included because their response is statistically different from the majority of other cultivars of that crop. An analysis based on these more extreme responses can serve to place some bounds on the assumed "more representative" responses captured in Analyses I and II. Analysis III thus uses the single cultivars available for barley and sorghum in combination with the nonheterogeneous cultivars of corn, soybeans, wheat and cotton.

The assessment also requires a base ozone level for use in the calculation of yield changes. Since the economic model is calibrated to 1980, 1980 ozone levels are a logical benchmark for use in the hypothetical ozone analyses. These 1980 values underlie Analyses I, II and III. However, annual variation in seasonal ozone levels is quite high for some areas, amounting to 40 percent in some cases. As an alternative, the years from 1978 to 1982 are averaged and the average values are used as a second characterization of base ozone levels. These new ambient ozone levels for each region are then used to evaluate the four ozone situations, i.e., the 10, 25, and 40 percent changes are now calculated relative to the alternative ozone base level. The response functions used in the evaluation are those for the first analysis (the national pooled responses). This set of four model solutions is identified as Analysis IV.

The presence of drought or moisture stress within some NCLAN field plots has shown an ambiguous relationship with respect to the effects of ozone on crop yield. However, for a few replicated studies, drought stress reduced the effect of ozone on yields; i.e., had an antagonistic effect. Thus, if plants are drought stressed during high ozone levels, the effects of ozone, as predicted by controlled experiments when plants are typically well-watered, may overstate the effects of ozone. This possibility has important implications in a national assessment, where from 50 to 90 percent of the acreage of major crops are grown under nonirrigated conditions. Ideally, response functions that reflect the ozone-water stress interactions could be used in combination with some meso-scale drought data to assess more accurately the economic effects of ozone under real world conditions. Unfortunately, such a complete data set currently does not exist. However, limited data are available on ozone-water stress interactions from three NCLAN experiments. In addition, an NCLAN crop simulation model provides some information on the influence of water stress on ozone effects (King and Snow, 1984). The results of these studies can be used to provide some preliminary quantitative adjustments to those non-water stressed response functions generated from NCLAN data. Using these limited observations, a fifth general analysis (Analysis V) examines the economic impact of ozone effects on crops in the presence of water stress.

These five analyses, combined with the four ozone levels and the base case, result in 21 distinct evaluations using the economic sector model formulation. Analysis I generates an overall impression of ozone effects. Analyses II through V are analyses of the sensitivity of the economic estimates to varying yield assumptions. The results of these analyses, including aggregate economic effects on producers and consumers provide a detailed prediction of the probable economic effects of ozone on agriculture under a range of conditions.

The results obtained with the economic base model are evaluated by comparison with actual values realized in 1980. The base model outputs of primary concern are the equilibrium prices and quantities produced for included crops and livestock products. The values of these variables, derived endogenously in the model solutions, are those that optimize the mathematical problem inherent in the model specification. Thus, validation of these values against actual 1980 levels establishes the general performance of the model.

Overall, the modeled prices and quantities are quite close to actual values. All model prices fall within 3 percent of actual prices. Predicted quantities are generally within 10 percent of actual. Other model features, including the net social benefit estimates (objective function value) and regional production patterns are also close to actual values for the base year. This validation of the general equilibrium model indicates that the base model can serve as an accurate benchmark against which to gauge the economic effects of ozone-induced yield changes.

The economic effects generated within the model are estimates of the changes in consumers' plus producers' surplus of those involved with the agricultural sector, as stimulated by a change in ozone. This quantity is equivalent to the sum of the agricultural sector-related income lost or gained by producers and consumers as a consequence of air pollution changes. The term "benefit" is used to indicate a gain in agriculturally-related consumers' and producers' surplus. Similarily "costs" (negative benefits) will be used to indicate losses. The calculation of consumers' and producers' surplus does not include compliance costs required to achieve the alternative ozone concentrations evaluated in this analysis. Also, the effect of ozone changes on non-agricultural goods and services are not evaluated. Thus, the benefits reported here should not necessarily be interpreted as net benefits to society associated with the ozone changes evaluated in this study.

The results of Analysis I, as measured against the base case, indicate that the annual benefits (in 1980 dollars) to society from ozone adjustments are substantial. The 10, 25 and 40 percent changes in ozone below ambient ozone levels result in benefits of $.756, $1.937, and $2.859 billion, respectively. A 25 percent increase in ozone results in an annual loss (negative benefit) to society of $2.363 billion. These economic estimates are 0.7, 1.4, 2.0 and 1.7 percent of the economic value of the included crops and livestock commodities predicted in the base model. The average yield changes giving rise to these economic changes are adjustments of 1.0, 2.5, 3.5, and 3.0 percent, respectively.

These estimates include yield adjustments for hay, based on the average yield response of the other crops. Hay is an important crop in a national assessment because of its role in the feed-livestock balance. An analysis using Analysis I ozone yield effects was also performed holding hay yields constant. If hay yields are not varied as ozone changes, the corresponding results are $0.669, $1.712, $2.518 and $-2.096 billion. Thus, the hay effect is approximately 13 percent of the economic estimates.

Both consumers and producers benefit at ozone levels lower than ambient in this assessment, with approximately 60 to 70 percent of the total benefits accruing to consumers. Consumers benefit from reduced prices arising from increased supplies. About 60 percent of the consumer benefits accrue to foreign consumers as manifested in export markets. Producers' benefits arise from the complex nature of supply curve shifts and the inclusion of the export sectors in the model; i.e., non-parallel shifts of the supply curves result in producer benefits in the face of varying demand elasticities for some commodities. On a regional level, the producers in the Pacific (California), Delta, Northeast and Southeast regions experience the greatest relative gains from ozone reductions. This is due to a combination of high ambient ozone levels and a mix of ozone-sensitive crops (soybeans, cotton) in those regions, as well as some shifting of regional market shares at alternative ozone levels.

Analyses II through V provide some measure of the sensitivity of the economic estimates to assumptions concerning response and ozone data. Analysis II indicates that the effect of pooling cultivar data regionally, rather than across all cultivars, as in Analysis I, is trivial. This observation suggests that the response bias arising from aggregating all statistically similar cultivars into one common response is minimal. Analysis III shows a much more dramatic difference in economic estimates when compared with Analysis I (approximately a 60 percent difference). Analysis III uses the most extreme cultivar response available for soybeans, corn, wheat and cotton. Statistically and agronomically, however, these cultivar (yield) responses behave unlike the other NCLAN cultivars for those crops. As such, these economic estimates are upper bounds on potential impacts as manifested if the current NCLAN response data capture the extremes in ozone sensitivity within the entire set of commercial cultivars. Analysis IV demonstrates that the annual ambient ozone levels used in the assessment do affect economic estimates but, like Analysis II, the difference is small (5 to 14 percent) between 1980 levels and a five year average. A more important issue may be the measure of dose (e.g., seven-hour or twelve-hour) rather than variability in the measure. Finally, Analysis V represents an attempt to include an antagonistic hypothesis concerning drought stress-ozone effects in the assessment. Compared with Analysis I, the economic estimates are about twenty percent lower. This difference is important, in that water stress and other environmental interactions occur commonly under commercial agricultural production conditions. There are currently insufficient data to fully incorporate such interactive stresses in economic assessments.

A number of limitations or caveats need to be attached to these estimates. While the estimates are derived from a conceptually sound economic model implemented with the most recent supporting data, there are several sources of uncertainty or error. These include the issue of exposure dynamics (seven-hour vs. twelve-hour), and the lack of environmental interactions, particularly ozone-moisture stress interactions, in many of the response experiments. Each of these response issues is being addressed in current NCLAN research. Also, the ozone data are based on a limited set of USEPA's Storage and Retrieval of Aerometric Data (SAROAD) monitoring sites, mainly in urban and suburban areas. While the spatial interpolation process (Kriging) results in a fairly close correspondence between predicted and actual ozone levels at a few validation points, there is a need for more monitoring sites in rural areas. The large scale economic model, with its many variables, parameters and the underlying data used to derive these values, is a potential source of error. The model is a long-run equilibrium model and assumes that supply will be consumed at some price. The model was validated against historical values, and hence its policy utility is greatest when addressing changes bounded by historical levels, rather than quantum adjustments. The modest adjustments portrayed in the ozone analyses fall within these historical levels.

THE ECONOMIC EFFECTS OF OZONE ON AGRICULTURE

I. INTRODUCTION

The harmful effects of ozone and other air pollutants on vegetation have been documented for at least 35 years (Middleton et al., 1950; Brisley and Jones, 1950; Beasdale, 1952). Such damages are now one criteria by which Secondary National Ambient Air Quality Standards (SNAAQS) are evaluated, as established by the Clean Air Act and its Amendments. Within the vegetative effects category, primary research emphasis has been placed on measuring effects on agricultural crops, given the importance of food and fiber to human welfare.

Attempts to assess the monetary impact of these agricultural effects followed (e.g., Benedict et al., 1971). While assessments of air pollution costs (or benefits of control) have not been used in setting secondary standards, such information may be used for this purpose in the future as well as in support of regulatory policy relating to secondary standards as required by Executive Order 12291 (Padgett and Richmond, 1983). Until recently however, economic assessments of ozone control to agriculture have been plagued by sparse or even contradictory biological information on which to base an assessment. Where data did exist, the procedures by which the data were generated did not readily lend themselves to economic analysis, as described in Adams and Crocker (1982). As a result, the validity of many assessments is questionable.

Conducting economic assessments on agriculture or other ecosystems requires specific biological response data linking pollutant levels and performance parameters of the ecosystem in question. For agricultural assessments, this response is represented by a relationship linking crop yield to air quality (or pollutant exposure levels) and other causal factors. The relationship may be quantified directly using data generated from biological experimentation, indirectly from observed producer output and behavioral data or from some combination of data sources. From the standpoint of economic analysis, procedures that are based on observed producer data, such as typically used in production function estimation or dual cost function techniques, are preferred (Crocker et al., 1981).

While some success has been achieved in applying both primal and dual cost procedures to agricultural assessments at the state level (e.g., see Mjelde et al., 1984), assessors in general have had little success in directly applying such techniques across large geographical areas, due to both data and statistical difficulties (e.g., see Adams et al., 1982; Manuel et al., 1981). Even for those regional studies where plausible estimates are obtained, related experimental data are required to formulate testable hypotheses as well as to establish the credibility of estimates derived from behavioral data (Mjelde et al., 1984, Rowe et al., 1984). As a result, national level assessments of pollutant damages to agriculture currently rely on supplemental data from some form of biological experimentation to define the relationship between exposure and plant yield response. The closer these experimental procedures are to real world or commercial production conditions, the more useful they become in economic assessments.

National Crop Loss Assessment Network (NCLAN) scientists recently have attempted to improve the state of knowledge regarding crop response to air pollutants (Heck et al., 1982). Conceived in 1980, this program involves field experiments on major agricultural crops to provide information on crop response to ozone, the most pervasive ambient air pollutant. The output from these experiments will ultimately form the basis for policy-making by supporting assessments of the national consequences of ozone on agriculture. Although some controls are imposed on the structure of the field experiments, the NCLAN data are generated so as to be at least minimally compatible with most economic assessment techniques. Performance of a preliminary economic assessment using these data is one objective of the NCLAN program.

This manuscript is a report on the preliminary NCLAN national economic assessment of ozone effects on agriculture. The analysis, data and results underlying this assessment represent the collective biological, meterological and economic knowledge gained from the NCLAN program through 1983. This knowledge is reflected in the biological response models and the economic methodologies used to derive the economic estimates. These data are the most defensible currently available for assessing the effects of ozone on agriculture.

The overall objective of this paper is thus to provide background, documentation and resultant estimates of the economic consequences of ozone on major U.S. agricultural crops under alternative levels of ambient ozone. The economic analysis is limited to those ozone effects directly associated with the production and consumption of a set of agricultural commodities. Effects on non-agricultural goods, as well as compliance costs of achieving any changes in ambient ozone levels are not evaluated here, hence the estimates should not necessarily be interpreted as net economic effects. The results are derived from an economic analysis based on a U.S. agricultural sector model (adapted from Chattin et al., 1983). Empirical emphasis is on six major crops (corn, soybeans, wheat, cotton, grain sorghum, and barley) which account for over 75 percent of U.S. cropped acreage (USDA, 1982). Potential ozone effects on hay are evaluated using the average yield response of other crops as a surrogate. In addition, the assessment accounts for the derived-demand relationship between feed grains, such as corn, and livestock by including a livestock production and feeding component.

The specific objectives of the analysis are:

1. to provide assessments of the economic consequences of alternative ambient ozone levels within the agricultural sector, including those accruing to both producers and consumers of agricultural commodities; compliance costs will not be examined.

2. to test the sensitivity of these economic estimates to varying yield forecasts reflecting sources of uncertainty within the NCLAN response data; and

3. to use these results to provide insight on the importance of improved information for possible inclusion in subsequent economic assessments of ozone effects on agriculture.

The next section briefly discusses biological and economic issues concerning the conduct of economic assessments and the use of dose-response information. Following this, the economic methodology and model are presented, along with the procedures and data sources underlying that analysis. Next, the results of the application of the economic model to the U.S. agricultural sector under alternative assumptions regarding ozone levels, response data and environmental interactions (ozone-moisture stress) are presented. Finally, policy implications and areas for further research are discussed.

II. A REVIEW OF ASSESSMENT ISSUES AND PAST STUDIES

In view of the importance of U.S. agriculture to both domestic and world consumption of food and fiber, major reductions in supply due to air pollution could have a substantial effect on human welfare. Biological research, such as that coming out of NCLAN and earlier studies, indicate that crop yields may be reduced substantially under current ambient ozone levels.

Given that ambient ozone levels during the growing season are sufficient to reduce yields of important crops in many agricultural production areas (e.g., the Corn Belt, the Southeast), the potential for substantial economic effects exists. For example, the five state Corn Belt region (Iowa, Illinois, Indiana, Missouri and Ohio) produces over 50 percent of the two principal crops in the U.S., corn and soybeans. As noted in Table 1, even modest changes in crop yields could translate into a sizeable economic effect, in view of the $33 billion farm value of just these two crops. Crops for which NCLAN data are available amounted to over $50 billion in farm value in 1981. An economic assessment of ozone on only these six major commodities thus can capture a major portion of the national economic consequences of this pollutant.

The potential for major economic effects from ozone has resulted in numerous attempts to assess dollar losses (or the benefits of pollution control) attributable to ambient ozone and other pollutants. Most studies predate the availability of NCLAN data for major agricultural commodities. Identification of critical assessment issues and an evaluation of how well these are addressed in past assessments can serve to strengthen the conceptual and empirical basis of the current NCLAN assessment, as well as provide some perspective on the general magnitudes of the economic consequences of ozone damages to agriculture.

Biological and Practical Issues

The need for plant response information measured in terms of yield units (rather than foliar injury) has been noted by most analysts doing assessment research (e.g., Leung et al., 1978; Adams and Crocker, 1982). Plant scientists also recognized the need to report response in terms of yield if economic losses are eventually to be estimated. For example, Oshima and coworkers (Oshima, 1973; Oshima et al., 1976; Oshima and Gallavan, 1980) have reported crop losses in terms of potential or actual yield reduction for a few crops. However, the NCLAN program (Heck et al., 1982) appears to be among the first coordinated national plant science research efforts to provide response information in a usable form for economic assessments. The NCLAN data and yield projections are discussed in more detail subsequently.

Table 1. 1981 acreage and value of major U.S. commodities included in NCLAN economic assessment

Crop	Acres Planted (millions)	Value of Production ($ billion)
Corn	84.106	20.001
Soybeans	70.087	12.943
Wheat, winter	57.425	7.692
Wheat, spring	23.005	2.534
Alfalfa hay	26.269	9.212[a/]
Other hay	33.168	
Grain Sorghum	15.894	2.032
Cotton	14.461	4.109
Barley	8.283	1.169
Total, NCLAN Crops	332.698	59.602
Total, All Crops	356.881	74.984
NCLAN Crops as Percentage of total	93.22	79.60

[a/] Includes all hay.

SOURCE: USDA, Agricultural Statistics, 1982.

Past attempts to assess the agricultural value of pollution control typically did not involve adequate plant science information. As a result assessors used a wide range of data sources and this lead to some highly divergent dollar-loss estimates of pollution damage. Such divergences may be attributable to some specific biological and air quality data issues or problems:

1. The effect of sparse data on pollution-induced crop losses. A lack of data caused assessments to be based on extrapolations from available foliar injury estimates resulting in often unreliable yield-reduction estimates.

2. Selection of alternative cultivar and crop mixes, regions, and time periods in the analysis. Crop prices, production levels, and ozone exposure vary geographically and temporally, with resultant changes in dollar loss estimates.

3. Selection or definition of alternative background ambient levels to portray "clean air" (absence of anthropogenic ozone) in the analysis. When used in combination with a standardized dose-response function, the use of different background ozone levels provides different yield reduction estimates and ultimately different economic estimates.

4. The difficulty of extrapolating from controlled chamber experiments to agronomic regions with all the required assumptions regarding soil type, precipitation regimes, pollution exposure patterns, solar radiation levels, and interactions among these edaphic and climatic variables.

In addition, alternative assessment techniques have been employed. It is not possible to sort out the relative contribution of better economic methodologies vis-a-vis better technical data to assessments of environmental regulation. However, recent empirical work of Adams et al. (1982) suggests that adequate representation of both economic and biological process contribute equally to the measurement of net benefits. The implication of this observation is that knowing both biological and economic responses is important in performing economic assessments.

Economic Issues

Decision making related to the formulation of public policy centers on perceived changes in "public welfare." There are alternative criteria by which to judge changes in aggregate public welfare arising from policy actions (Harberger). However, in a benefit-cost analysis of ambient air quality changes, regulatory actions typically do not lead to regulations from which all parties benefit. Virtually any air pollution control action or regulation will disadvantage someone (polluters, consumers, agricultural producers) in terms of perceived welfare. A measurable or quantitative definition of welfare is needed as a basis for judging socially desirable changes associated with alternative pollution control actions. This also implies the need for common or consistent measures of value for the various welfare components.

The economically accepted measures of welfare are compensating and equivalent variation as reflected in economic surplus measured through consumers' and producers' surplus (see Just et al., 1982, or Willig, 1976 for definitions and more extensive discussions). Consumers' and producers' surplus represent the utility gained by individuals when: (1) in consuming goods, they obtain goods at a price less than the maximum they would be willing to pay; and (2) in producing goods, they sell at a price above the price at which they would have been willing to supply. Most economic assessments of environmental controls now measure benefits in terms of economic surplus. A graphical presentation of these surpluses under a wide range of air pollution situations is presented in Adams et al. (1984). In addition to using consistent benefits or welfare measures in an environmental assessment, the forces or processes that give rise to changes in welfare need to be identified and modeled.

For example, the physical effect of air pollution on vegetation reflects the natural or physiological processes associated with the toxin in question. However, the varying economic impacts of air pollution on agricultural producers may be a function of such factors as: 1) edaphic factors and endowments; 2) production systems and alternatives; 3) geographical location; 4) types of agricultural crops planted; 5) availability of substitute crops; and 6) managerial ability. Consumers of these agricultural products can be classified into strata or groups based upon such factors as: 1) income level; 2) regional location; 3) percentage of income spent on food; and 4) food and other preferences. While consumer surplus is an accepted measure of aggregate welfare, the nature and distribution of impacts within the consumer category is another dimension of welfare. Several distributional issues which then arise in an assessment of air pollution policies include:

1. How are gains and/or losses distributed between various classes of people (for example, tradeoffs between consumers and producers)?

2. How are gains and/or losses distributed regionally, commodity-wise, or among factor owners?

3. What might be the impact of an action in terms of strata within a class (e.g., farm size or income distribution)?

4. How do the distributional effects change with time?

The latter two distributional concerns are difficult to address due to insufficient data. However, the use of techniques which ignore or are incapable of addressing the first two distributional consequences will result in misleading estimates whenever: 1) prices in the output or input markets in the agricultural sector are sensitive to changes in yield and input usage from varying levels of air quality; and 2) producers and consumers adopt different means for adjusting to changes in air quality.

In the first case, if the percentage yield increases caused by air quality improvements are less than the resultant percentage price reductions, an assessment that ignored such price effects would attribute benefits to the producer when in reality there would be producer revenue losses (and consumer gains). The second concern relates to producer (or consumer) adaptation strategies. For example, if producers can adopt different production patterns (or utilize more resistant cultivars or adopt other compensatory input changes, such as adding lime and fertilizer) and thereby reduce their potential losses (or increase gains) from an air pollution increase, they will do so. Failure to account for this adaptive producer behavior will result in overestimates of losses experienced by producers in the face of air quality degradation. Similarly, consumers may substitute certain agricultural commodities in the face of relative price changes, so that the net effect of a rise in the price of a commodity due to air pollution-induced supply changes may not be as severe as first indicated.

Assessment Methodologies Applied to Agriculture

Air pollution-agricultural assessments found in the literature fall within three broad methodological categories. Only one of these categories features methodologies that are capable of addressing the above issues. The first type uses damage functions to report crop losses in physical units such as the reduction in actual or potential crop production in a given geographical unit (e.g., a state or region). Examples include the recent work by Loucks and Armentano (1982) and the "DAMAGE" model defined in Moskowitz et al. (1982). This type of assessment makes no claim to report economic losses. The second (and most prevalent type of assessment of those reporting dollar losses) translates the physical losses obtained from damage functions into a dollar value by multiplying estimated yield losses by an assumed constant crop price. For the purposes of this section, this ad hoc approach is defined as the "traditional" procedure. As an economic assessment methodology, it suffers from serious conceptual weaknesses, which limit the validity of the estimates to some very restrictive cases. Thus, not all dollar loss estimates (such as those obtained from this approach) should be viewed as valid economic estimates. The third assessment type features the use of theoretically justified economic methodologies that address some of the economic issues raised in the preceeding section. Such studies provide estimates of benefits of control in dollar terms which account for producer-consumer decision-making processes and hence distributional consequences of alternative environmental states. These estimates will more accurately reflect the economic effects of air pollution in those situations where economic processes and markets are known to operate, as in the case of agricultural production. Dollar estimates arising from traditional and economic assessment methodologies are seldom distinguished in the popular press. However, economists generally discount the monetary estimates obtained from the traditional or damage function type of assessment (critiques of this approach may be found in Leung et al., 1978, and Crocker, 1982).

The advantage of the traditional procedure is the relative ease with which dollar values may be obtained. More comprehensive economic assessments, as exemplified by Leung et al. (1982), Benson et al. (1982), Adams et al. (1982), Mjelde et al. (1984), Kopp et al. (1983) and Adams and McCarl (1983) attempt to account for market impacts of air pollution-induced yield reductions and producer behavioral responses. These studies involve somewhat different techniques as determined by the structure of the particular economic problem (i.e., duality, mathematical programming, econometric-simulation). However, they all explicitly deal with price adjustments, providing estimates of the economic effects on various economic agents, such as producers and consumers. In the Benson et al. (1982) and Adams et al. (1982) studies, the results obtained from these comprehensive economic analyses were compared with estimates obtained from the traditional procedure,using the same data. The differences were moderate to large, with the traditional procedure overestimating losses from air pollution when a "clean air" and ambient ozone condition (an environmental degradation) were compared. Also the traditional procedure provides estimates which at best can only address producers' effects with no attention paid to the fate of consumers. Thus, there are fundamental, conceptual and empirical differences between losses measured by the traditional procedure and those obtained from more comprehensive economic assessments. A detailed review of alternative economic techniques and their suitability to environmental economic assessments is presented in Freeman (1979).

A Review of Regional Assessments

Most of the economic assessments in the literature focus on regional effects. This regional emphasis may be attributed to the relative abundance of data on crop response and air quality for selected regions, as well as the national importance of some agricultural regions (such as the Corn Belt and California). While regional estimates are not sufficient for evaluating alternative national air pollution standards, such studies can provide useful comparative information on alternative economic methodologies for assessing environmental damages. Also, regional estimates may be indicative of the potential magnitudes of national effects, if that region (e.g., the Corn Belt) produces a dominant share of major commodities such as corn and soybeans. Economic estimates of pollution effects for selected regions are presented in Table 2.

Of the regional studies reported in the literature, several have focused on southern California, a region with both high pollution (ozone) levels and an important agricultural economy. Adams et al. (1982) assessed the impact of ozone on 14 annual vegetable and field crops in four agricultural subregions of central and southern California for 1976 using a price-endogenous, quadratic-programming approach. Their model solution predicted the effects of changed ozone levels and associated yield and price changes on the welfare of producers and consumers. Ozone-induced reductions in yield were derived for most crops from the Larsen-Heck (1976) foliar injury models. The authors then estimated what crop production and price would have been if the 1976 federal secondary ambient air quality standard (80 ppb not to be exceeded more than once a year) had been achieved.

The estimated losses from current ambient ozone were found to be relatively small when compared with total agricultural value in the region -- approximately $45 million compared to a total agricultural value of nearly $2 billion. Elimination of 1976 oxidant pollution would have increased 1976 producer surplus by $35 million and ordinary consumer surplus by $10 million.

Table 2. Summary of recent regional air pollution control benefits estimates

Region	Reference	Annual benefits or loss estimate ($ millions)	Comments
Southern California	Adams et al 1982	43-45	Estimated as economic surplus in 1976 dollars for 14 annual crops. Employs mathematical programming model to evaluate benefits of reducing current ambient levels to seasonal seven-hour ave. of 40 ppb.
South Coast Air Basin (California)	Leung et al. 1982	93-103 (300)[a]	Losses estimated as economic surplus in 1975 dollars for citrus, avacados and selected annual crops. Employs econometric procedures to compare "clean air case" (no oxidant pollution) with ambient levels.
Ohio River Basin	Page et al. 1982	278[b] (6,960)	Losses estimated as producer losses for corn, soybeans, and wheat in 1976 dollars. Region includes Illinois, Indiana, Ohio, Kentucky, West Virginia, and Pennsylvania.
Minnesota	Benson et al. 1982	30.5[d]	Losses estimated in 1980 dollars for corn, alfalfa, and wheat under alternative ozone assumptions. Farm level dollar losses obtained from econometric model of national commodity markets.
Corn Belt	Adams and McCarl 1984	668	Uses a sectoral model of U.S. agriculture to record economic effects of changes in yields of corn, soybeans, and wheat due to alternative oxidant standards. Benefits include effects on both consumer and producer of a more stringent federal standard (80 ppb).
Illinois	Mjelde et al. 1984	55-200[e]	Uses profit functions to measure effect of ozone on producers' profits. Aggregate effect over corn, soybeans, and wheat assuming a 25 percent reduction in ambient ozone.
California	Howitt et al. 1983	37	Benefits measured as an increase in economic surplus from a reduction in ambient ozone to 40 ppb seasonal 7-hr average. Analysis based on a mathematical programming model of California annual crops.
California	Rowe et al. 1984	46-117	Benefits measured as increase in economic surplus arising from meeting three alternative California oxidant standards. Uses mathematical programming model of major California annual and perennial crops.

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[a] Estimate of direct and indirect losses for entire state.

[b] Estimated annual equivalent loss due to oxidants.

[c] Present value of losses due to oxidants for 25 year period (1976-2000).

[d] "Worst case" ozone situation, ignores production effects outside Minnesota. If other regions included in analysis, worsening of ozone increases total gross returns to Minnesota producers by $67 million due to inelastic nature of commodity demand.

[e] Range of economic benefits due to a 25 percent reduction in ozone from ambient levels over a four-year period (1978-1981).

By way of comparison, Adams et al. applied the traditional approach to estimating losses (multiplying the estimated difference between actual and potential yield for 1976 by market price) and derived a total estimated loss of $52.5 million. While the difference appears relatively small, the traditional method only measures effects on producers. If the latter figure is compared with the producer loss from the economic analysis, the result is an approximately 50 percent greater loss estimate for the traditional procedure, largely because of the inability to accommodate offsetting price changes and producer mitigative adjustments.

Leung et al. (1982) estimated ozone damage to nine annual and perennial crops in the California South Coast Air Basin, representing some 40 percent by value of crop production in the region. Rather than use an experimentally based measure of dose-response, Leung et al. estimated yield loss with yield functions derived from secondary data. Crop-yield reductions were estimated for 1975 by calculating the differences between actual yields with 1975 levels of ozone and yields predicted by the linear response functions at zero ozone concentration. Using the predicted yield adjustments from these yield functions to drive the analyses, Leung et al. (1982) then calculated changes in consumers' and producers' surplus to approximate the welfare effects of changes in agricultural supply brought about by ozone. Demand and supply curves were estimated with data from 1958 to 1977 and then used to calculate 1976 losses of consumer and producer surplus from ozone exposure of $103 million.

There are two more recent studies of the effects of air pollutants on California agriculture. In the first, Howitt et al. (1984) assess the impact of alternative ozone levels on the statewide production of fourteen annual crops. The economic model is similar to that employed in Adams et al. (i.e., a price-endogenous, quadratic programming model), updated to 1978 values. The response data are derived from NCLAN experiments, with the exception of alfalfa, which is taken from Oshima et al. (1976).

The analysis examines three ozone scenarios, reflecting hypothetical changes in ambient ozone to 40, 50 and 80 ppb seasonal seven-hour averages. The first is a reduction approximately equivalent to meeting a Federal standard of 80 ppb hourly maximum (about a 25 percent reduction in ambient ozone assuming the hourly maximum is about 2 times the seasonal seven-hour mean). The second portrays a slight degradation (increase) in ozone. The 80 ppb analysis portrays an increase of about 33 percent in ambient ozone. The economic effects of meeting the two extreme ozone actions are a $36 million net benefit (from the 25 percent reduction in ozone) and a $157 million loss. The 50 ppb analysis amounts to a slight degradation in air quality and hence a very small economic loss. These effects are in line with those observed in Adams et al.

The second study, by Rowe et al. (1984), focuses on both annual and perennial crops in the San Joaquin Valley of California, the major production area of the state. Using both field and experimental data, Rowe et al. estimate a series of yield functions for the major crops grown in the San Joaquin Valley for both ozone and sulfur dioxide (SO_2). With the exception of potatoes, no yield changes arise from the ambient SO_2 levels. The yield adjustments for ozone are then used to drive the same economic programming model used in Howitt et al. (1984).

The ozone analyses of Rowe et al. feature greater ozone reduction and hence greater yield adjustments than those of Howitt et al. As a result (and perhaps because of the broader crop coverage) the benefits of control are larger, amounting to from $48 to $117 million, depending on the ozone assumption. These results, in combination with earlier California studies, provide evidence of some substantial air pollution effects, but the distribution of these impacts appears to be felt most heavily by the producers of the commodities. The Rowe et al. study also provides some support for use of combined secondary (survey) and experimental data as a means to overcome a lack of response effects information for a broad range of crops.

Losses within the Ohio River Basin (Illinois, Indiana, Ohio, Kentucky, West Virginia, and Pennsylvania) were estimated by Page, et al. (1982). The region is a major producer of corn, soybeans, and wheat; it also experiences oxidant levels sufficiently high to depress crop yields. Although the study examined two pollutants, SO_2 and ozone, the largest losses (approximately 98 percent) were attributed to ozone levels. The yield reduction data were derived from Loucks and Armentano (1982), who synthesized experimentally determined crop loss data and extrapolated the results to air quality concentrations in the Ohio River Basin. Losses were measured at the producer level as changes in producers' income (quasi-rents) between clean air and ambient ozone levels and corresponding losses (minimal, maximum, and probable) were projected over the 1976 to 2000 period, and the estimated loss expressed in 1976 dollars. The net present value of ozone-induced losses across the various loss scenarios for the 25-year period is approximately $6.8 billion, or an annual equivalent of $278 million. Not surprisingly, the bulk of these losses is estimated to accrue to the states with the largest agricultural production, Illinois and Indiana.

The Page et al. and some other economic assessments (Manuel et al., 1981; Leung et al., 1982) utilize a crop by crop approach, so that substitution between crops is not considered. Such substitution is contained in the Adams et al. programming-based study. Smith and Brown (1982) assess in detail the importance of substitution between differentially sensitive crops (acreage shifts between crops) in response to ozone-induced yield changes or to relative crop price changes with a farm level linear programming model. Yield changes are predicted with the Loucks and Armentano (1982) ozone-response model. For the profit maximizing producer, such substitution should occur if ozone levels change, because soybeans are considerably more sensitive to ozone than corn. Such relative sensitivity and its potential effects on economic estimates has been noted earlier by Adams and Crocker (1979), Adams et al. (1979), and Leung, et al. (1978).

Studies which fail to consider cross-crop substitution may lead to biased estimates of changes in consumer and producer surplus from reduced ozone. Such studies will tend, ceteris paribus, to underestimate the increase in consumer surplus for crops which are more sensitive to ozone than other crops, and tend to overestimate the increase in consumer surplus for crops that are less sensitive. If the economic benefits from pollution control standards are estimated in terms of changes in consumer and producer surplus caused by shifts in supply, then the effect of crop substitution on the assessment of the benefits to be gained by reducing ozone levels needs to be determined.

The linear programming model utilized by Smith and Brown assessed the impact of four different yield improvement scenarios on acreage shifts among corn, soybeans, and wheat. Comparison of each crop's acreage under different yield improvement scenarios reveals that as ozone levels fall, there is a shift from corn and wheat -- crops assumed to be more resistant to ozone damage -- to soybeans. Damage estimates equal to or greater than the Loucks and Armentano (1982) minimum yield loss estimate result in major shifts in cropping patterns as well as significant loss in net farm income. Allowing crop substitution increases the estimated economic gain to farmers (from reduced ozone) by up to 20 percent over the estimates from the non-substitution analysis.

A major limitation of this study for policy purposes is that only benefits accruing to producers are assessed. Crop demand was assumed totally elastic so that output price would not change when supplies shifted. Although such an assumption is valid at the farm level, the pervasive nature of ozone pollution in the Corn Belt and that region's market share of corn and soybeans suggests that the effects of price responses arising from aggregate supply shifts should be considered.

In a model of crop losses induced by ozone stress in Minnesota, Benson et al., (1982) also provide estimates of the economic consequences of ambient ozone. Yield loss functions for alfalfa, wheat and corn are evaluated at the county level with actual or simulated 1980 ozone data.

Benson et al. aggregate the estimated potential yield losses occurring at ambient ozone concentrations for each county to provide a statewide crop loss. A national econometric model was then used to convert yield (production) adjustments for each crop into dollar losses, under alternative supply assumptions: (1) assuming ozone, and hence production, is unchanged in areas outside of Minnesota (analytically the same as the traditional procedure); and (2) assuming that ozone levels change nationwide and then accounting for supply and demand relationships for each crop as affected by production changes in all regions. The assumptions gave highly divergent estimates of effects on Minnesota producers. For example, the estimated dollar loss attributable to a worst case ozone level obtained from the first assumption is approximately $30 million in 1980 dollars. Conversely, when the econometric model accounted for price changes (measures) resulting from probable changes in production to all regions, it indicated that there would be a gain to producers of $67 million in the short run if ozone levels increased (in Minnesota as well as other production areas for these crops). These results, when combined with similar observations from Adams et al. (1982) and Leung et al. (1982) suggest the importance of assessment methodologies that account for regional market linkages and resultant price effects in performing economic assessments of a pervasive environmental problem.

Mjelde et al. (1984) employ duality concepts in their analysis of the effects of ozone on Illinois cash grain farms. In addition to measuring the direct economic consequences of ozone on farmers' income, this analysis demonstrates the methodological utility of the duality approach. One of the primary objectives of their effort is to test whether a meaningful link can be established between the physical loss estimates generated under controlled experimentation and the physical response information inherent in observed economic behavior (i.e., farmers' cost data). To explore this, Mjelde et al. (1984) invoke duality concepts in developing profit functions for Illinois grain farms.

Profit functions are estimated from a large sample of detailed cost and production data for Illinois farms and incorporate environmental variables (i.e., ozone, temperature, and rainfall) as well as traditional economic variables. In most specifications, ozone is revealed to have a negative and significant (at the 5% level) impact on profit. When direct production effects (elasticity) of ozone are compared with NCLAN results obtained at Argonne National Laboratory in Illinois (Heck et al., 1983a), the production responses appear to be reasonably close. Specifically, the aggregate (across three crops -- corn, soybeans, and wheat) output elasticity from Mjelde et al. is -0.132. For a 25% increase in ozone, it is estimated that aggregate output for the three crops would decline 3.3 percent. The same 25 percent increase using the Argonne data indicates an 11.7 percent and 3.7 percent decrease in output for Corsoy and Williams cultivars of soybean, respectively. For two corn cultivars (Pioneer 3780 and PAG 397), output would decline between 1.4 and 0.6 percent. The Mjelde et al. aggregate production estimate (of 3.3) lies between these estimates.

Finally Mjelde et al. calculate that ozone resulted in an aggregate loss in profits to Illinois farmers of approximately $50 million in 1980. This estimate is based on the ozone elasticity with respect to profit -0.43. Again, this result seems consistent with some previous loss estimates (Heck et al., 1983; Page, 1982).

A study of ozone effects on Corn Belt agriculture by Adams and McCarl (1984) uses a large-scale micro-macro economic model specification to measure effects of alternative oxidant standards on producers and consumers. Detailed farm level models designed to capture producer responses are interfaced with a national sector model to measure aggregate effects. The model is an earlier version of the economic model used in the current NCLAN national assessment. The analysis is driven by NCLAN response functions for the Corn Belt generated through the 1982 crop year and includes region-specific response data for corn, soybeans, and wheat. Changes in yields associated with hypothetical federal secondary oxidant standards as suggested by the NCLAN data provide the basis for the analysis. The results of the analysis suggest that reduction in oxidants (lowering the present standard to 80 ppb from 120 ppb) would provide a net benefit of $668 million. Conversely, relaxing the standard to 160 ppb would result in a loss to consumers and producers of approximately $2.0 billion. In terms of distributional consequences, this analysis follows shifts associated with changes in supply in the face of inelastic demand. That is, the 80 ppb scenario (of increased production) benefits consumers at the expense of producers, whereas the 160 ppb assumption results in the opposite situation.

A Review of National Assessments

Properly structured national analyses overcome a fundamental limitation of regional analyses by accounting for economic linkages between groups and regions. However, detailed national assessments also tend to be more costly to perform. As a result, there are fewer estimates of pollution effects at the national than the regional level. Of the national assessments performed since 1980, several use the traditional, ad hoc approach to quantify dollar effects. Analyses of this type tend to ignore the economic concept of benefits, as discussed earlier. However, some of the most recent national assessments included in this review do use more defensible measures of economic effects. National level estimates of air pollution damages are summarized in Table 3. As indicated in the table, the range of estimates is relatively small. Caution should be used in making comparisons between these estimates, however, as the analyses employ somewhat different crops, response information and assessment approaches, as detailed below.

The recent national level economic estimates of ozone effect to agriculture include an assessment by the Stanford Research Institute (SRI) for the National Commission on Air Quality (1981). This is an updated version of the Benedict et al. (1971) study. The intent was to estimate the benefits of meeting the Secondary National Ambient Air Quality Standards for ozone and sulfur dioxide accruing to 16 agricultural crops. The principal methodological differences between the earlier Benedict et al. approach and the SRI approach include the use of a wider range of dose response functions drawn from the plant science literature through 1980, updated production data from the 1974 Census of Agriculture and updated air quality and price information.

SRI estimated the decline in total production from oxidants and sulfur dioxide emissions using the updated response functions and county-level data on air quality for non-attainment counties (531 counties). These physical loss estimates were then translated to a dollar value by the ad hoc procedure of multiplying the reduction in production by the 1980 crop price for each commodity. The resultant dollar loss estimate (or potential benefit of meeting the secondary national ambient air quality standards for ozone and sulfur dioxide) was reported to be $1.8 billion (1980 dollars) for agricultural crops. Note that this entire amount is assumed to accrue to producers, as the method is incapable of measuring consumer effects. Of this total, the benefits of meeting the oxidant standard are far greater than the direct benefits of meeting SO_2 standards ($1747 million compared to $34 million), because the number of nonattainment counties for oxidants is nearly six times the number of nonattainment counties for SO_2.

Another study assessing the benefits to be gained by reducing air pollution was conducted by Manuel et al. (1981). Their investigation centered on estimating the potential benefits for cotton and soybean production of achieving alternative secondary national ambient air quality standards for sulfur dioxide (SO_2) and total suspended particles (TSP). The estimated demand equation included the prices of soybeans, corn and substitutes. On the supply side, cross sectional data were utilized to estimate crop yields;

Table 3. Summary of recent estimates of national economic consequences of pollution

Study	Crops	Annual Benefits of Control	Comments
Stanford Research Institute (1981)	corn, soybeans, alfalfa and 13 other annual crops	$1.8 billion	Updated version of Benedict-SRI model. Loss measured in 1980 dollars for 531 counties.
Shriner et al. (1982)	corn, soybeans, wheat, peanuts	$3.0 billion	Effects estimated in 1978 dollars, measured at producer level. Control assumes a background or "clean air" oxidant level of 25 ppb ozone. Uses NCLAN response information for 1980.
Adams and Crocker (1984)	corn, soybeans, cotton	$2.2 billion	Benefits measured in 1980 dollars using economic surplus. Benefit represents difference between current production and production if an ambient ozone level of 40 ppb had been achieved Uses NCLAN response information for 1980.
Adams, Crocker, and Katz (1984)	corn, soybeans, wheat, cotton	$2.4 billion	Benefits measured as economic surplus in 1980 dollars. Benefits arise from the increase in production due to a reduction in ozone from 53 ppb to approximately 40 ppb. Response information from 1980, 1981, and 1982 NCLAN data.
Kopp et al. (1983)	corn, soybeans, wheat, cotton, peanuts	$1.2 billion	Benefits measured as economic surplus in 1978 dollars. Benefits due reduction in Federal standard from 120 ppb to 80 ppb hourly-maximum. Uses NCLAN response information from 1980 and 1981.

variables included fertilizer per acre, lime per acre and SO_2 level. An acreage response for each crop is estimated as a function of the crop's expected price, the expected price of a substitute crop and government support programs for that crop. Supply was subsequently estimated as the product of the yield equation and the acreage response function. Estimated changes in producer and consumer surplus are attained by a simply dynamic model.

The Manuel et al. (1981) econometric model improved on the traditional procedures used in the SRI analysis in that it includes price effects across crops, and hence accounts for crop substitution in response to changes in output prices. The model framework also does not require the direct use of experimentally derived dose-response functions; instead, production function concepts are used to account for ozone and SO_2 impacts on production. However, the statistical robustness and stability of the SO_2 yield-coefficients are disappointing. Further, as with any aggregate econometric approach, the model is unable to reflect compensatory input adjustments or the substitution which may occur as farmers choose to plant more of some crops and less of others because of relative yield changes.

A national assessment by Shriner et al. (1982) for the Office of Technology Assessment estimated the losses associated with ambient ozone levels for four crops -- corn, soybeans, wheat, and peanuts. The study employed dose-response information from early NCLAN experiments and simulated county-level ozone data generated from available USEPA Storage and Retrieval of Atmospheric Data System (SAROAD) monitoring sites. With the crop-response information and county-level ozone data in combination with 1978 Census of Agriculture data on yields, percentage reductions were measured against a base or "background" ozone level of 25 ppb ambient concentration. As in the SRI study, the estimated physical reduction in county production levels for each crop were then converted to a dollar value by the traditional ad hoc procedure of multiplying by the county-level price. The aggregate loss (or difference between value of production at ambient levels and those at 25 ppb) for the United States was estimated at approximately $3 billion. The benefits estimates suffer from the same problems as those associated with the SRI and other approaches that abstract from economic factors. The principal improvement of this study over the SRI assessment is in the use of 1980 NCLAN data.

Another economic estimate of ozone pollution effects was developed by Adams and Crocker (1984), who used information on ozone-induced plant effects to determine the sensitivity of resultant economic estimates to additional plant response information. However, the study also presents a numerical estimate of ozone damage to three crops, representing about 60% of the value of U.S. crop output (corn, soybeans, and cotton), using response data derived from 1980 and 1981 NCLAN experiments (Heck et al., 1982).

In developing these estimates, Adams and Crocker used linear ozone dose-response functions (derived from NCLAN results), and estimated farm-level demand and supply relationships with relatively simple general equilibrium functions. The response data, combined with the structure of the commodity markets in questions, were used to compare the benefits to consumers and producers of progressively more stringent control schemes. The estimated difference in economic surplus between ambient ozone levels and a seasonal seven hour average of 40 ppb was approximately $2.2 billion.

Another national level estimate of the economic consequences of ozone on corn, soybeans, cotton and wheat is reported in Adams et al. (1984). This study builds on some of the methodology used in Adams and Crocker (1984). While the primary purpose of the analysis was to measure the adequacy of natural science information in performing economic assessments, the derivation of a series of benefits functions also provides an approximation of the benefits of changing ozone levels on the four crops included in the study. Benefits are calculated in terms of Marshallian surplus estimated from the integration of supply and demand curves for each crop under alternative ozone levels. Yield effects are generated with both linear and quadratic response functions.

The benefits of an assumed reduction in ambient ozone (to 40 ppb) across the entire U.S. is estimated to be approximately $2.4 billion in 1980 dollars. A 25 percent increase in ozone (to 66 ppb) results in a net loss of $3.0 billion. These benefits and costs are probably upper bounds, due to producer micro-response that may mitigate for changes in ozone and the use of an assumed current ambient concentration of 53 ppb (associated with the present Federal standard) for all production regions. This ambient level is the upper bound seasonal seven-hour concentration for major production areas as reported in the SAROAD data. To the extent that all regions are equal to or less than this amount, the benefits of reductions in ozone are overestimated and the losses of ozone increases are underestimated.

Finally, a recent assessment by Kopp et al. (1983) measures the national economic effects of changes in ambient ozone level on the production of corn, soybeans, cotton, wheat and peanuts. The study is notable in that the assessment methodology is based on development of a series of detailed cost structures for "representative farms" which are then aggregated to regional and national supply responses. Like some of the programming based studies, this methodology places emphasis on developing reasonable micro or producer-level responses to yield changes. The effects of ozone on the yields of the included crops are based on NCLAN data through 1981. Response functions of the Box-Tidwell type are fit to these data. Predicted yield changes associated with alternative secondary standards are then used to shift the regional supply response relationships. The price and consumption effects are measured through a set of demand relationships for each commodity, reflecting a range of elasticity assumptions.

The results of the analysis indicate that a reduction in ozone from regional ambient levels to an approximate 40 ppb seasonal seven-hour average would result in a $1.1 billion net benefit. Conversely, an increase in ozone to an assumed ambient concentration of 80 ppb across all regions would produce a net loss of approximately $3.0 billion. These values of ozone reductions are slightly less than those reported in Adams and Crocker (1984), and Adams et al. (1984). The differences may be attributable to the finer regional and farm scale resolution in Kopp, et al., as well as different ambient base ozone levels (lower than the 53 ppb in Adams et al., 1983), and different elasticity assumptions vis-a-vis these other studies. While the Kopp et al. methodology appears to force the entire economic adjustment process onto what is perceived to be the high cost production region and does not address such issues as crop substitution, it reinforces the need for detailed representation of the economic processes underlying agricultural production in performing policy analyses of ozone pollution.

While these national assessments represent continued improvement over time, some common limitations should be noted. For example, most of these benefits estimates from decreasing ambient pollution levels are conditional on the assumption that those levels across a given region would not exceed the assumed level; i.e., assumes that pollution levels are uniform across all crop-production areas. If the actual concentrations are lower or vary across agricultural areas, then the benefits accruing to the implementation of national standards would be different, with the direction of change dependentf on the relative share of consumer and producer benefits in total benefits. Also, potential producer adjustments to changes in pollution levels beyond those observed in historical patterns are not addressed in any of these national studies. Thus, if past adjustments serve to define the range of responses, effects from as yet unrealized ozone levels may be biased.

This review of past and current studies of air pollution effects on agriculture indicates that quantitative techniques are available to address the important conceptual dimensions of the assessment problem. To date, these techniques have focused primarily on regional effects, due in part to a lack of defensible plant science and meteorological data across major crops and regions. With the availability of data from NCLAN, credible national economic assessments are now feasible. The next section discusses the economic methodology to be used in this preliminary assessment. Among the set of theoretically defensible techniques, it appears most compatible with the data and the nature of this assessment problem. Some of the other assessment methodologies discussed in this review are also capable of pro viding theoretically defensible benefits estimates, but it is our belief that the employed methodology provides a broader range of policy infor mation on ozone control. The reasoning behind this assertion is presented in the methodology discussions.

III. METHODOLOGY

Economists have devoted considerable effort to assessing the consequences of policy or technically induced change on participants within the agricultural sector. Many types of changes have been examined. For example, Freeman (1979) reviews approaches examining the consequences of environmental change; Feder, Just and Zilberman (1983) examine the consequences of technical changes on agriculture, and the preceeding discussion has reviewed the effects of alternative air pollution levels or policies on agriculture. The assessments of such changes have been performed at different levels of generality within the agricultural sector. In particular, assessments of the benefits of change have been performed at both the farm and sectoral levels. Analysis at each of these levels potentially leads to quite different results. For example, it is not difficult to imagine a case in which the analysis on a single Corn Belt farm would lead to the conclusion that a ban on pesticides without effective substitutes would lead to Corn Belt farmers receiving less income. But conversely, when considering a similar ban where the pesticide is widely used throughout the Corn Belt on commodities subject to inelastic demand, it is possible that an increase in farm sector gross revenue would occur while consumers would lose. Ultimately, changes in producer welfare will be a function of the characteristics of demand and supply. Thus, there are potentially major differences in the results of such evaluations depending upon the level at which the evaluations are performed. This suggests the need to consider broader implications in evaluation of induced change rather than simply isolating the farm level effects as economists have traditionally done (Heady and Srivistava, 1975; McCarl and Spreen, 1980; and Norton and Schiefer, 1980 review such larger efforts).

Focusing on broader effects typically involves research tradeoffs. The evaluation of changes at the sectoral level often require one to sacrifice microeconomic detail in order to keep the problem tractable. This can have serious consequences. For example, when doing appraisals of induced change with aggregate programming models (i.e., models such as those used in Heady and Srivistava, 1975; Baumes, 1978; or Burton, 1982) one often finds extreme specialization in production. That is, one gets solutions where whole regions are devoted to a single crop. This situation usually leads to the imposition of inflexible "flexibility" constraints (Sahi and Craddock, 1974). However, McCarl (1982a) recently argued that a way to avoid this specialization in production and thereby generate more plausible results within a sectoral analysis was to link microeconomic considerations with the sector model through a Dantzig-Wolfe decomposition scheme using heuristic procedures. The analysis used in this assessment incorporates the McCarl methodological proposal in the context of the induced change analysis due to ozone. Implementing the methodology requires both detailed farm-level models and a macro or sector model.

In this study the agricultural sector model component is a price-endogenous mathematical programming model of the agricultural sector; i.e., an activity analysis spatial equilibrium model (Takayama and Judge, 1971). Such sector models have been used extensively by agricultural economists to simulate the effect of alternative agricultural policies or technological change (Heady and Srivistava, 1975; Duloy and Norton, 1973). Among the various methodologies available to formulate policy models, mathematical programming has proven to be a particularly useful tool given its ability to predict potential consequence of as yet unrealized policies. This general methodology has been applied to air pollution effects in the Adams et al., 1982; Adams and McCarl, 1984; Howitt et al., 1984; and Rowe et al., 1984 assessments reported in the previous section.

In addition to the sector model, a series of farm models based on (1) linear programming (LP) models and (2) analyses of historical data were used. The LP-based farm model (REPFARM, McCarl, 1982b) was implemented for representative farms in the Corn Belt. These LP-based representative farms were developed by Brown and Pheasant (1983). Each REPFARM model was run under a large set of alternative crop prices to develop a set of whole farm plans which consisted of mixtures of corn, soybeans, wheat, oats and double crop soybean acreage. For areas outside the Corn Belt, historical data were used to generate whole farm plans. Crop records by state for 1970-1981 were used both to develop representative state level crop mixes and to derive econometrically estimates of crop yield changes associated with crop mix changes. These econometric procedures were intended to model regional acreage-yield relationships, as discussed below. In turn, the whole farm plans from both sources were used to generate activities for the sector model (originally developed by Baumes, 1978 and documented in Chattin et al., 1983) utilizing the USDA FEDS budgets. The sector model was then solved under the alternative ambient ozone scenarios. Thus, the informal procedure proposed by McCarl (1982a) was utilized, in which the representative LP farm models for the Corn Belt and the crop mixes and regional acreage-yield relations for other regions were used to generate a number of activities for use in the sector model. Such detailed specification and estimation of crop-mix activities was to overcome the aggregation problems identified in McCarl (1982a).

We now turn our attention to a detailed discussion of the farm model, the sector model and the linkage of these models to assess the economic impacts of ozone on agriculture.

The Farm Model

As noted above, the mathematical programming model applied here consists of both a micro or producer level component and a macro component. The features of this particular model are discussed in more detail elsewhere (McCarl et al., 1983). The mathematical programming sector model contains activities which represent production and consumption of various commodities. The production and consumption sectors are assumed to be made up of a large number of individuals, each of whom maximizes some objective function under competitive market conditions. Specifically, each producer is expected to maximize profits subject to a set of technical and behavioral constraints. That is:

$$\text{Profits} = \sum_{k=1}^{n} \left(\sum_{h=1}^{m} p_h z_{hk} - \sum_{i=1}^{s} r_i x_{ik} \right)$$

where:

p_h is the market price per unit of the h$\underline{\text{th}}$ output (h=1,..., m); and

z_{hk} is the yield of the h$\underline{\text{th}}$ output from the k$\underline{\text{th}}$ production process (h=1,..., m; k=1,..., n);

r_i is the market price per unit of the $i\underline{th}$ purchased factor (i=1,..., s).

x_{ik} is the use of the $i\underline{th}$ purchased factor in the $k\underline{th}$ production process (i=1,..., s; k=1,..., n);

This constrained profit maximization problem is then specified as a mathematical (linear) programming problem (McCarl and Spreen, 1980). Necessary and sufficient conditions for solution of a constrained maximum problem are defined by the Kuhn-Tucker conditions, conditions easily traced to standard microeconomic marginal conditions for profit maximization. The analytics of this linkage are presented in Appendix A.

In this analysis, producer level behavior is portrayed by the series of linear programming representative farms for the Corn Belt region. The representative farms for the other production regions are based on FEDS budgets which define input and output relationships to represent crop production. Specifically, 12 rep-farms are modeled within the five-state region designated as the Corn Belt by the USDA. These rep-farms are assumed to mimic the input-output or technical and economic environment of the producers in a given region. The farms are modeled with considerable detail on cropping activities (twelve annual crops plus hay and beef, pork, and milk production), input use, and environmental and other fixed constraints. Multiple activities are defined for a given crop in a given region to cover the wide range of production technologies available to producers. Such detail is needed to model adequately potential producer mitigative behavior in the face of environmental changes. As noted by Crocker (1982), failure to account for these adaptive opportunities tends to overstate potential damages and understate benefits.

The multiple activities (within crops) generate the set of primary agricultural commodities that interface with the sector models. These primary commodities are listed in Table 4. In addition to crops, the analysis also includes livestock products. An endogenous livestock component is needed, given that livestock are the "consumers" of most of the primary crop commodities, as well as accounting for approximately 50 percent of economic activity in the agricultural sector.

The farm model used was the REPFARM programming model (McCarl, 1982b; McCarl and Pheasant, 1982; Brown and Pheasant, 1983). This model was used to develop representative farms for a series of substate regions in the Corn Belt. The REPFARM model facilitated a definition of various possibilities involving continuous corn, rotation corn (rotated with soybeans), rotation soybeans, oats, single crop soybeans, wheat and double crop soybeans in these areas utilizing location specific timing of planting and harvesting, along with different sequences of other crop cultural operations and different yields for each crop by type (continuous, etc.), planting, and harvesting date. The data used in the representative farms were based on agricultural statistics, extension reports, existing models and expert opinion (see Brown and Pheasant, 1983; for details). The representative farms for the thirteen subregions were run with different corn prices and twelve different soybean to

Table 4. Primary commodities included in the economic model

Commodity	Units
Field Crop Commodities	
Cotton	1000 bales
Corn	1000 bushels
Soybeans	1000 bushels
Wheat	1000 bushels
Sorghum	1000 bushels
Oats	1000 bushels
Barley	1000 bushels
Rice	1000 cwt
Sugar cane	1000 tons
Sugar beets	1000 tons
Silage	1000 tons
Hay	1000 tons
Livestock Commodities	
Milk	1000 cwt
Culled dairy cows	1000 head
Culled dairy calves	1000 head
Culled beef cows	1000 head
Live heifers	1000 cwt
Live calves	1000 cwt
Non fed beef available for slaughter	1000 cwt
Fed beef available for slaughter	1000 cwt
Calves available for slaughter	1000 cwt
Feeder Pigs	1000 cwt
Hogs available for slaughter	1000 cwt

corn ratios as well as five different wheat prices. This results in 300 different price ratios for each of the representative farms. These data were summarized to yield a series of unique crop mixes (i.e., land use patterns including all crops following the procedure in McCarl, 1982a) and accompanying yields for each of the representative farms in the Corn Belt. To develop representative farms for the states outside the Corn Belt, crop mixes and corresponding base yields were derived from acreage and yield response relationships estimated from historical data, as discussed below. These whole farm crop mixes and yield adjustments were then used in combination with the FEDS crop budgets for each state or region to generate a range of farm level activities for the crops in the analysis.

Generation of Other State Activities and Crop Mixes

The yield-acreage response relationships observed over time in regions outside the Corn Belt are used to develop a mix of crop activities from the FEDS budgets for these regions. This procedure, in combination with the Corn Belt individual LP models, is intended to provide an economically and technically realistic portrayal of producer's behavioral responses. These relationships are derived econometrically from historical patterns on relative crop acreage (percentage of a unit land area devoted to each crop). Each crop mix implies a given cost structure and corresponding yield. Since yields are expected to change with crop mix, these yield adjustments are predicted by the yield-acreage response functions. Specifically, the yield of a crop can vary, not only in response to the acreage planted of that crop, but also the the acreage planted of other crops.

The rationale and procedure used to derive econometrically the yield-acreage relationships is described in detail in Appendix B. In general, however, the procedure involves estimating a system of yield equations expressed as a function of crop acreages ("own" and "other") and other variables based on historical data from 1970 to 1981. These relationships were then "normalized" to a 1980 base value. This gave rise to a series of annual crop mix-yield adjustment ratios. The ratios are used in combination with the FEDS crop budgets for each crop to generate a set of farm level activities that portray various cropping alternatives for each state representative farm.

The alternative to explicitly accounting for these relationships would have been to simply use the FEDS budgets and a given annual crop mix to define crop alternatives (activities) for each representative farm. While analytically simpler than trying to account for crop mix-yield changes, this was not done because it ignores potentially important yield response information. Specifically, since expected profit is assumed to be a primary factor in the producers planting decision (acreage and crop mix) and since these acreage and crop mix decisions can affect yields, it is important to account for these responses in the modeling of farm level production. If the yield response relationship is ignored, the acreage response arising from changes in expected profit would likely be overstated. This would then bias a subsequent ozone analysis where changes in relative crop yields are used to portray the effects of alternative ozone levels.

The Sector Model

The producer level responses generated through the REPFARM model and the historical data analyses are interfaced with the macro component of the sector model to obtain a measure of social benefits (McCarl et al., 1983). Consistent aggregation is achieved by building on the above micro conditions, which allows the aggregate and micro processes to be linked. These linkages are demonstrated analytically in Appendix A. The macro model features constant elasticity of demand relationships for the outputs (commodities) of the micro models. The elasticities vary with end use and across domestic and export markets. Given the long-run nature of the model, export demand assumes major importance. Export demand elasticities for corn, sorghum, wheat, soybeans, soybean oil and soybean meal are derived from Burton (1982) who cites the USDA Forecast Support Group as the source. The export elasticities vary, from -.15 for corn, to -1.53 and -1.98 for soybeans (whole) and sorghum, respectively. Assuming supply and demand functions which are integrable and independent of sector activity, first order conditions are then achieved in macro model specification. The objective function of this specification is:

$$\text{Maximize} \qquad \Pi = \sum_i g_i(Z_i) - \sum_j e_j(X_j) - \sum_m C_m Y_m$$

where Π is the sum of ordinary consumers and producers' surplus and the integrals are evaluated from zero to Z_i*, the amount of the i^{th} commodity produced and sold to consumers; and from zero to X_j*, the amount of the j^{th} factor used. The parameters are as follows:

$g_i(Z_i)$ is the area under the demand function for the i^{th} product;

$e_j(X_j)$ is the area under the supply function for the j^{th} factor;

C_m is the miscellaneous cost of production,

subject to a set of technical and behavioral constraints. Given the micro and macro structure of a model, the sector model solution then simulates a long-run, perfectly competitive equilibrium. The full empirical detail of the objective function is provided in Equation (14) of Appendix A.

Following Samuelson (1952), the objective function (Π) may be interpreted as a measure of ordinary consumers' and producers' surplus (quasi-rents) or net social benefit. Analytically, this is defined as the area between the demand and supply curves to the left of their intersection. The demand functions are specified at the national level, as are aggregate production responses. Thus, the solution of the sectoral model provides objective function values at the national level.

The linking of the detailed producer behavioral model with a macro model measured in (changes in) consumers' and producers' surplus provides a useful policy model. Justification for the use of economic surplus in policy analysis is well documented in the literature (Willig, 1976; Just et al., 1981) and is particularly relevant to agricultural uses where aggregate distributional consequences are of concern. By imposing alternative ozone levels on the rep-farm behavior, as manifested in yields predicted by the NCLAN response functions, changes in production and consumption and ultimately economic surplus may be measured. Comparisons of changes in consumer and producer surplus between the alternative ozone levels and current ambient concentration indicates the benefits for these alternative ozone levels.

The sector model was solved under a mix of demand curves (constant elasticity, stepped demand, each displaying a range of elasticities) using the MINOS software package (Murtaugh and Saunders). It is structured (in a two-region example) as in Figure 1. The model encompasses production, processing, domestic demand, export demand, and imports. A simplified tableau appears in Figure 2. The basic data utilized in implementing the model are United States Department of Agriculture Firm Enterprise Data System (FEDS) budgets. The United States is disaggregated into ten regions consisting of the 48 states but with the Corn Belt (Iowa, Indiana, Ohio, Illinois, Missouri) disaggregated into 12 subregions. This results in a total of 55 production regions. The primary crop coverage (commodities) were presented in Table 4. Table 5 summarizes the secondary commodities arising from these primary items. For the purpose of this study, the FEDS budgets for 1978, as reformatted and expanded by Burton (1982) were updated to 1980, using 1980 yields, acreages, and prices. The modified budgets include transportation costs, chemicals, machinery, fuel and repairs and interest. Labor and land availability depends on endogeneous prices. The miscellaneous production costs were altered following the procedures outlined in Fajardo, McCarl, and Thompson (1981); or Baumes (1978). (These procedures involve calculating miscellaneous costs so that the miscellaneous costs exactly equaled the difference between the value of production and the cost of the endogenously priced inputs within the model.)

Definition of crop production alternatives was handled in two ways, depending on region. Crop production activities for regions outside the Corn Belt were defined using the adjustments reflected in historic yield and acreage trends over the period 1970-1981 as explained above and in Appendix B. Within the Corn Belt, activities were formed by aggregating the corn, soybean, oats, and wheat activities according to the whole farm crop mix plans generated by the representative farm models. Specifically, the REPFARM model when, run for a particular price ratio, yielded a particular combination of crops; for example, 45 percent corn, 35 percent soybeans, and 20 percent wheat with associated yields outside the Corn Belt. Under the historical data procedure, crop mixes were constructed which consisted of the percentage of each crop (e.g., 45 percent corn, 15 percent wheat, 35 percent cotton and 5 percent soybeans) during a particular year. Associated relationships were estimated which gave crop yield as a function of own crop acreage, other acreage, and other variables, as noted above. Eleven historic alternative crop mixes and associated yields were developed (1971-1981). The crop mixes for both the Corn Belt and other regions were then aggregated into budgets for whole farm multiple crop plans by taking the budget item for each crop times the percentage of that crop grown. In addition, yields within these composite budgets were developed as follows. A base ratio was selected from the microeconomic model or the data, giving the typical cropping pattern which led to the 1980 yield statistics. Then the yield for a particular cropping pattern was divided by the base yield, to obtain the proportional relationship between yield under this crop mix and base yields. Subsequently, the FEDS crop budget yield was multiplied by this relationship and by the proportion of corn to generate corn yield for the multiple crop budget. Thus, if the crop mix represented 90 percent corn, whereas in the base situation (1980) there was 50 percent corn, then the yield procedure above would account for a

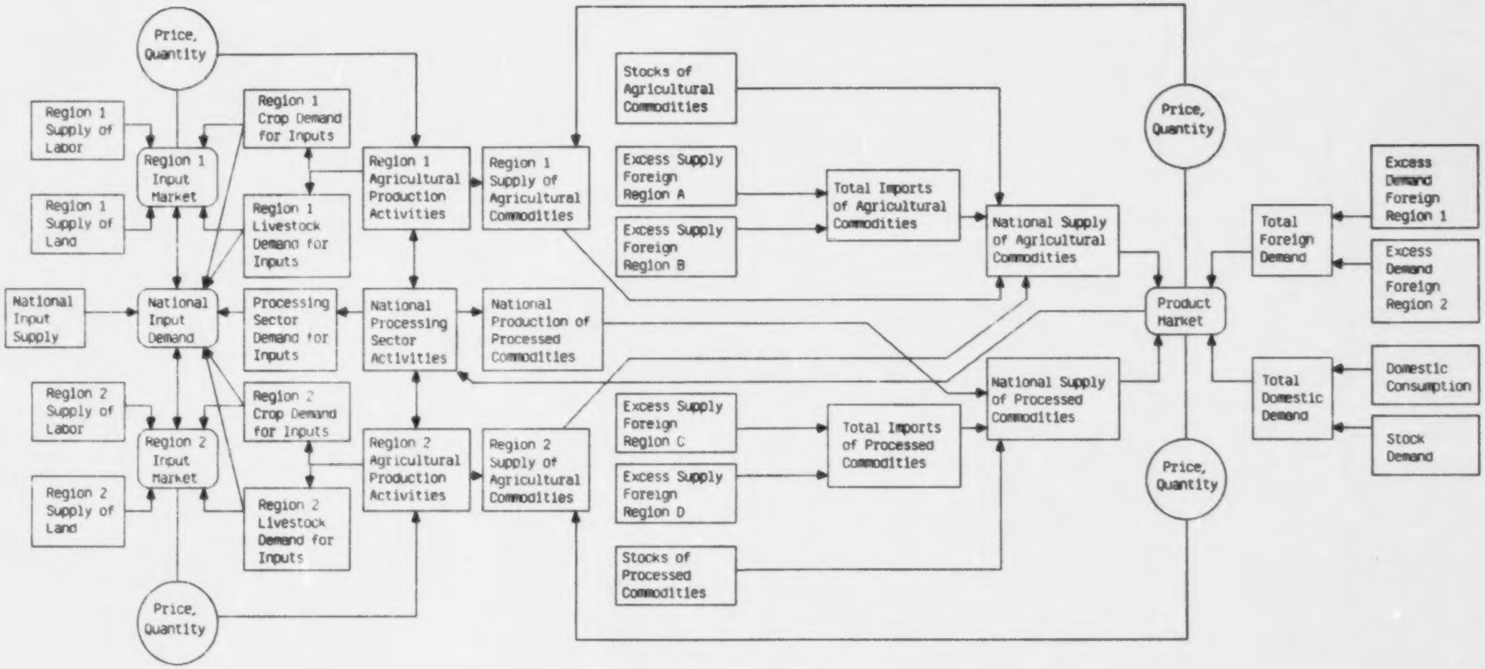

Price, Quantity
Region 1 Supply of Labor
Region 1 Supply of Land
Region 1 Input Market
Region 1 Crop Demand for Inputs
Region 1 Livestock Demand for Inputs
Region 1 Agricultural Production Activities
Region 1 Supply of Agricultural Commodities
National Input Supply
National Input Demand
Processing Sector Demand for Inputs
National Processing Sector Activities
National Production of Processed Commodities
Region 2 Supply of Labor
Region 2 Supply of Land
Region 2 Input Market
Region 2 Crop Demand for Inputs
Region 2 Livestock Demand for Inputs
Region 2 Agricultural Production Activities
Region 2 Supply of Agricultural Commodities
Price, Quantity
Stocks of Agricultural Commodities
Excess Supply Foreign Region A
Excess Supply Foreign Region B
Total Imports of Agricultural Commodities
National Supply of Agricultural Commodities
Excess Supply Foreign Region C
Excess Supply Foreign Region D
Stocks of Processed Commodities
Total Imports of Processed Commodities
National Supply of Processed Commodities
Price, Quantity
Product Market
Price, Quantity
Total Foreign Demand
Excess Demand Foreign Region 1
Excess Demand Foreign Region 2
Total Domestic Demand
Domestic Consumption
Stock Demand

Figure 1. Structural features of the sector model.

	National Input Supply	Region 1			Region 2			Production Region 1		Production Region 2		Processing Activities	Demand - Primary Products				Demand - Processed Products			Importation			RHS
													Domestic Use				Domestic Use						
		Family Labor	Hired Labor	Land	Family Labor	Hired Labor	Land	Crop	Live-stock	Crop	Live-stock		Crops	Live-stock	Stock	Foreign (Exports)	Consumption	Stocks	Foreign (Exports)	Crop	Live-stock	Processed	
Objective Function	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+				≤ +
Labor: Region 1		-	-					+	+														≤ +
Region 2					-	-				+	+												≤ +
Land: Region 1				-				+	+														≤ +
Region 2							-			+	+												≤ +
National Inputs	-							+	+	+	+												≤ 0
Crop Market Clearing								+	-	+	-		+		+	+				-			≤ 0
Livestock Market Clearing									-		-	+		+							-		≤ 0
Processed Goods Market Clearing												-					+	+	+			-	≤ 0
Production Regulations								+	+	+	+												≤ +
Processing Regulations												+											≤ +
Input Regulations	+	+	+	+	+	+	+																≤ +

Figure 2. Simplified model tableau.

Table 5. Secondary commodities in the economic model

Commodity	Units
Soybean meal	1000 lbs.
Soybean oil	1000 cwt.
Poultry Feed	1000 lbs.
Feed grains	1000 lbs.
Protein supplement dairy feed	1000 lbs.
High protein livestock feed	1000 lbs.
High protein swine feed	1000 lbs.
Low protein swine feed	1000 lbs.
Veal	1000 cwt.
Non-fed beef	1000 cwt.
Fed beef	1000 cwt.
Pork	1000 cwt.

reduction in corn yields experienced in the micro model due to expanded corn acreage, i.e., less favorable corn planting conditions.

Finally, demand levels for products and the supply prices are drawn from 1980 agricultural statistics. As discussed earlier, elasticities used are from Burton (1982), and vary according to end use, for both domestic and export markets.

IV. PROCEDURE

The economic model, in combination with yield changes predicted by the NCLAN response function at alternative ozone levels, is used to generate estimates of economic effects due to ozone changes. Each of a series of hypothetical ozone scenarios is judged against a base case analysis. The difference between economic surplus in the base case solution and the hypothetical ozone analyses represents the benefits or costs of the ozone change. The base case is intended to reflect 1980 actual agronomic, meterological and economic conditions, i.e., the base case analysis is one where the economic model is run (solved) using 1980 actual parameters, including yields. This year was selected as a base year given the absence of any apparent disequilibrium conditions relative to other recent years. The credibility of the base modeling solution is established by comparing the predicted values of key variables, such as equilibrium prices and farm revenues with actual values for the base year. Establishment of a close correspondence between model output and actual values is needed to confirm the general validity of the model.

Once a plausible solution is established for a base case, the model is then solved using alternative yield values (modified from actual 1980 yields) that reflect hypothetical ozone levels in each production area (state or sub-state levels). The yield adjustments, measured as percentage or proportionate changes, are derived by use of an appropriate mix of NCLAN response functions with the respective hypothetical ozone levels. In this analysis four alternative ozone levels are evaluated: a 10 percent, 25 percent and 40 percent reduction in ambient ozone concentrations and a 25 percent increase in ozone (from 1980 and 1978-82 mean levels).

The effects of these changes in ozone on crop yields in each production area are estimated with selected NCLAN response functions. For crops where no NCLAN data exist (i.e., oats, rice, sugar beets, sugar cane), the yields are held constant (no change) over the various ozone levels. The exception is hay, as described subsequently. It should be noted that the use of NCLAN (or any other experimentally derived) response functions in an economic assessment assumes that the imposition of ozone is analogous to neutral technological change, i.e., efficient input combinations do not change in response to ozone and that other environmental stress factors (in addition to ozone) also remain unchanged (from the levels observed in the ambient environment of the field chambers). The NCLAN functions used here are estimated from data generated through the 1983 crop year. Given the large number of response functions available for some crops, a series of assumptions are made as to which are most appropriate for use in a broad scale assessment of this type. Following Rawlings and Cure (1984), a Weibull density model specification of the relationship between ozone and yields is adopted. Among the set of functional forms tested by NCLAN statisticians, the Weibull has been selected as the most reasonable (and flexible), based on biological and statistical considerations (Rawlings and Cure, 1984, Heck et al., 1983b). Within this functional form, however, there are still eleven cultivars of soybeans, three of corn, eight of wheat, and two of cotton from which to choose, as well as individual cultivars for grain sorghum and barley. In addition, some cultivars are replicated over several years, resulting in more data sets than cultivars for some crops; e.g., there are 17 data sets for the nine soybean cultivars.

Initial screening of these cultivar responses with the Weibull model indicates that a common or "pooled" response for soybeans, wheat, and corn, estimated using data from multiple cultivars of each crop may be appropriate, given the statistically homogeneous proportionate response displayed by most cultivars. Thus, the pooled Weibull response models for corn, soybeans and wheat, in combination with Weibull models for irrigated (western U.S.) and non-irrigated (southeast) cotton cultivars and the single cultivars available for grain sorghum and barley constitute one possible cultivar mix. Using this set of response functions, the four ozone alternatives are then translated into corresponding proportionate yield changes. The economic effects of these four yield change situations are evaluated with four corresponding model solutions. This set of four evaluations constitute Analysis I. Through the use of the pooled data, this analysis incorporates nearly all the response information available from four years of NCLAN experiments.

One important commodity for which NCLAN data are not available is hay. Hay, in the form of alfalfa or grass-legume mixtures, is a dominant crop in several regions. It also plays a role in the feed-livestock balance and the resulting spatial characteristics of livestock feeding. While data are not currently available to directly gauge the effects of ozone on hay yields, one study of alfalfa hay response in California established a statistically significant relationship between yields and ozone (Oshima, 1976). While the Oshima study approach is unlike the NCLAN protocals, it does suggest that alfalfa hay yields are affected by ambient ozone. In view of this possible ozone sensitivity and the economic importance of hay, a "with" and "without" hay response evaluation is included in Analysis I. (Pasture and rangeland are also important in the production of livestock; they are not addressed in this hay analysis.) Specifically, the four ozone alternatives are first performed on the six major crops for which NCLAN data are available, holding the yield of hay constant at 1980 levels. Then, a hay response is included in the analysis by using the average response of the six NCLAN crops as a surrogate. This average response is used to adjust the yields of hay. The "with" and "without" hay analysis can suggest the importance of including hay in future assessments and hence the need for more hay response data.

The use of a pooled response for soybeans, corn, and wheat is based on the statistical homogeneity of response (slope) across the set of cultivars for each crop. This test of homogeneity (an "F" test on the estimated intercept and slope parameters of the respective Weibull models) implies that the proportionate response (or slope) of an individual cultivar cannot be shown to be statistically different from the response portrayed by another cultivar when fit with the Weibull density model. However, this does not imply that the cultivars predict identical yield changes for the same ozone level. Also, within a given crop, a few cultivars were shown to be non-homogeneous. For example, of the eight soybean cultivars, two did not show statistically homogeneous yield changes. Thus, it is possible that at the regional level, some subset of these individual cultivars may more accurately predict yield response. For example, of the eight soybean cultivars, some are restricted to different latitudes or maturity zones, such as Hodgson in the Lake States, Williams, Corsoy, Amsoy and Pella in the Corn Belt and Davis, Essex and Forrest in the south and southeastern states (Caldwell, 1973). These differences may then affect the economic estimates. To cover this possibility, a second general analysis is performed, where more region-specific cultivar responses are used for corn, wheat, and soybeans, in addition to the cultivars of cotton, grain sorghum, and barley used in the first analysis. The hay response as defined in Analysis I is also included. This next set of four ozone-yield solutions is identified as Analysis II.

Analyses I and II use various combinations of pooled responses for certain crops. In the pooled analyses, a few cultivars are ignored because of their heterogeneous nature. However plausible it may be to view these as atypical responses, it is nonetheless remotely possible that their response may characterize some regional response patterns. An analysis based on these more extreme responses can also serve to place some bounds on the assumed "more representative" responses captured in Analyses I and II. Analysis III thus uses the single cultivars available for barley and sorghum in combination with the most sensitive non-heterogeneous cultivars of corn, soybeans, wheat and cotton, along with the surrogate hay response.

The assessment procedure also requires judgments with respect to base level air quality used in the calculation of yield changes. Given that the projected yield changes are measured against an actual or base level of ozone, the value used to express the actual level is important. Since the economic model is calibrated to 1980, 1980 ozone levels are a logical benchmark for use in the hypothetical ozone analyses. These 1980 values underlie Analyses I, II and III. However, annual variation in ozone levels is quite high for some areas. For example, the range in seasonal ozone concentrations (as averaged over the April through September period) is in excess of 40 percent for the 1978-82 time period (Heck et al., 1983a). To smooth out some of this variability and ease the problems of using a given or "representative" year, alternative base years (from 1978 to 1982) are averaged and the average values are used as a second characterization of base ozone levels. (While not addressed here, the variability in ozone may have implications in terms of yield variability and hence producer risk.) These new ambient ozone levels for each region are then used to evaluate the four ozone situations, i.e. the 10, 25, and 40 percent changes are now calculated relative to the alternative ozone base level. The response functions used in the evaluation are those for the first analysis (the national pooled responses, with hay). This set of four model solutions or runs is identified as Analysis IV.

The pairing of a detailed economic model and the full set of NCLAN data is intended to provide economic estimates of ozone effects occuring under "real world" conditions. However, the NCLAN data do not specifically address the interactions between ozone effects as manifested in the field chambers and other environmental stress factors. For example, meterological records indicate that ambient ozone and temperature are positively correlated. This suggests that ambient ozone may be positively correlated with drought or moisture stress. The presence of drought or moisture stress within several NCLAN field experiments has been shown to reduce the effects of ozone on crop yields i.e., have an antagonistic effect. (One study displayed a slight synergistic relationship but the results were not replicated at the time this assessment was prepared.) If the antagonistic assumption is correct and if plants are drought stressed during high ozone levels, the effects of ozone, as predicted by controlled experiments when plants are typically well-watered, may overstate the effects of ozone. This possibility has important implications in a national assessment, where from 50 to 90 percent of the acreage of major crops within some subregions of the model are grown under non-irrigated conditions. Even if drought is not identified as a major meteorological event in a given growing season, non-irrigated crops probably still experience less than optimal moisture conditions at some point in the growing season.

Ideally, response functions that reflect the ozone-water stress interactions should be used in combination with some micro or meso-scale drought data to assess more accurately the economic effects of ozone levels on agriculture. Unfortunately, such a complete data set does not currently exist. However, limited data are available on ozone-water stress interactions from three NCLAN experiments, one on cotton and two on soybeans. In addition, an NCLAN crop simulation model also estimates the effect of water stress on ozone effects (D. King, personal communication). The results of these studies can be used to provide some crude quantitative adjustments to the fully watered response functions generated from NCLAN data. Using these limited observations, the fifth general analysis (Analysis V) examines the effect of ozone on crops in the presence of water stress. The cultivar mix again is that used in the first analysis (pooled or common response using 1980 ozone levels with a surrogate hay response).

These five analyses, in combination with the four ozone levels and the base case, result in 21 distinct economic assessments (model solutions) using the farm level-sectoral model formulation. The general assumptions underlying the 5 analyses are summarized in Table 6. Analyses II through V can be viewed as analyses of the sensitivity of the economic estimates to varying yield assumptions. The results of all these analyses, including aggregate economic effects on producers and consumers (the net economic effect) as well as the regional level effects on producer incomes, cropping patterns and land use are discussed in detail in the results section. However, to implement those procedures, considerable data, both from the NCLAN field experiments and from USEPA the air quality and meteorological sources, are needed. These data sets and modifications, where required, are discussed in detail in the following section.

V. THE DATA: SOURCES AND ASSUMPTIONS

Implementing the economic model and performing the five analyses requires biological and meterological information. This section discusses the sources of these data and assumptions inherent in their use.

Plant Response

A major goal of the NCLAN program is to develop a base of plant science information on the response of crops to ozone and other stresses. To accomplish this task, plant scientists working with the NCLAN program measure the yield response of crops to alternative ozone levels using open-top field chambers (Heck et al., 1982). Plants are exposed for seven hours per day (0900 to 1600) to ambient and alternative ozone levels. The 7-hour daily exposure is assumed to occur during the period of stomatal activity.

Currently, these data cover four years of crop experiments (1980-1983), conducted on multiple crops and cultivars at five sites in the U.S. The procedures and results of these analyses have been documented in literature prepared by the NCLAN Research Management Committee and the individual researchers (e.g., see Heck et al., 1982a; Heck et al., 1982b; Heck et al., 1983a; Heck et al., 1983b). In addition, Heck et al. (1984b) summarized all the NCLAN response information, in exposure-response form, for the four years of the program. This summary publication is the source of the individual crop response functions used in the economic analysis reported subsequently.

The response functions reported by Heck et al. (1984b) encompass both individual cultivars for each of the six crops and a set of common or "pooled" responses for each crop using multiple cultivars. The cultivars selected for experimentation at each NCLAN site are those commonly planted by producers in that region. However, many other regionally important cultivars are not tested. The pooled analysis of cultivars is one means of testing for potential errors in yield effects due to a small sample. Specifically, the pooled responses are estimated using data from sets of cultivars demonstrated to be statistically homogeneous (display the same proportionate response). Such pooling is one means by which the potential variability across individual sites can be tested. If responses generated at different geographical locations are deemed statistically homogeneous, then some of the acknowledged problems of extrapolation from specific sites to broader regional scales can be minimized. For some crops (barley and sorghum) only one cultivar has been tested and hence a pooled response is not possible.

The response functions (from Heck et al., 1983, 1984b) that are used in this economic analysis are summarized in Table 7. Note that all functions are reported in the Weibull form. Among the large number of functional forms (linear, linear plateau, quadratic, cubic) fit to the raw NCLAN data, the Weibull is assumed to be the most defensible based upon statistical and plant science considerations (Heck et al., 1983; Rawlings and Cure, 1984). The Weibull functions reported in Table 7 are used to project ozone-induced yield adjustments for each crop under the various analyses contained in the economic assessment.

The common or pooled responses, in combinations with the single cultivar available for barley and sorghum, are used to develop the first set of crop yield adjustments (reported in Appendix Tables D.3 to D.11) for use in Analysis I. Then, the more "regionalized" pooled response functions estimated from subsets of cultivars, in combination with the single cultivar crops, are used to develop the yield adjustments in a second general analysis (Analysis II). By using cultivar combinations showing statistically homogeneous response patterns, Analysis I and II are intended to minimize problems of extrapolation from data generated at specific sites to large scale regional effects. Finally, a set of response functions composed of individual cultivars that are not statistically homogeneous in response (as compared with the cultivars in the "pooled" response analyses) are used to predict yields. These responses are representative of the more extreme response possibilities for each crop. This set constitutes Analysis III.

Table 6. Summary of alternative assessment analyses: cultivar, ozone and stress assumptions

Analysis	Cultivar Mix	Ambient Ozone	Moisture Stress	Evaluation
I	Pooled response of all homogeneous cultivars for soybeans, corn, wheat, cotton; individual cultivars for barley and sorghum. Hay response measured as average of other crops.	1980 Seasonal Average	Not Treated	Pooled analysis based on all homogeneous cultivars. This analysis is intended to minimize extrapolation bias between sites and broad-scale assessments. Includes "with" and "without" hay adjustment analyses.
II	"Regionalized" pooled response for homogeneous cultivars of soybeans and corn. Wheat and cotton is in Analysis I. Individual cultivars for barley and sorghum. Hay measured as surrogate response.	1980 Seasonal Average	Not Treated	Analysis based on pooled data for homogeneous cultivars common to a given region.
III	Individual cultivars for all crops. Cultivars for corn, wheat, soybeans and cotton represent extreme yield effects in NCLAN data set. Hay measured as surrogate response	1980 Seasonal Average	Not Treated	Extreme analysis to test the sensitivity of the economic estimates to the maximum variability in cultivar response information.
IV	Same as used in Analysis I	Average of 1978-1982 Seasonal Average	Not Treated	Analysis is to test the effect of ozone year(s) on estimates. Smooths out variability in annual ozone levels.
V	Same as used in Analysis I	Same as Analysis I	Ozone response adjusted using NCLAN crop simulation model, 1980 July rainfall	Preliminary attempt to adjust for moisture stress. Can serve to suggest possible bias, in analyses that ignore other stress factors.

Ozone Data

To utilize the NCLAN response functions, two types of air quality data are needed. First, some measures of actual ambient ozone concentrations in rural production areas are necessary as a starting point. The ozone data must be presented in an exposure measure consistent with that used in the NCLAN experiments (seasonal average of the daily seven-hour concentrations) at a geographical scale sufficient to be compatible with the 55 production regions in the sectoral model. Ideally, actual ambient ozone data for all agricultural production areas in the economic model should be used. Unfortunately, such complete data do not exist, as the available data from USEPA's Storage and Retrieval of Aerometric Data (SAROAD) system are taken from predominantly urban monitors. However, a surrogate data set has been prepared (J. Reagan, USEPA, RTP). The procedures and county level results giving rise to this data set for five years (five growing seasons encompassing April through September measurements) covering the period 1978-1982 are discussed by Heck et al. (1983a).

The surrogate county-level ambient ozone concentrations are derived by a spatial interpolation of the USEPA SAROAD monitoring data. This interpolation between monitoring sites is based on a "Kriging" procedure that implicitly gives greater weight to nearest monitoring sites. It should be noted that some states have as few as three monitoring sites. Even where sites are more numerous (over 100 in California, for example), most tend to be in urban or suburban areas. Thus, this geographical interpolation of the national SAROAD data set is subject to some uncertainties. These potential sources of error are summarized in Heck et al. (1983a). However, certain meteorological aspects of ozone make this pollutant amenable to interpolation procedures; e.g., its pervasive nature and the existence of smooth gradients of concentrations rather than abrupt spikes or plumes. Further, the nature of the exposure measure (seasonal seven-hour average) is also assumed to "smooth" out some of the variability in the ozone events. A comparison of "Kriged" ozone levels in with some actual ambient concentrations recorded at NCLAN sites (Heck et al., 1983a) reveal a fairly close correspondence. Specifically, the Kriged estimates are generally within 5 percent of the measured means (the exception is California). While these characteristics perhaps make this procedure a defensible approach to fill in gaps in the rural ambient air quality data, its use is based ultimately on the absence of any better data. The resulting state level estimates of seasonal (April through September) seven-hour ambient ozone concentrations data for each year and for the period 1978-1982 are presented in Table 8. A broad regional breakdown of these data with annual variability is presented graphically in Figure 3.

The Kriged ozone concentrations for 1980 are used as the base ozone levels in Analyses I, II, and III. As an alternative base ozone assumption, the 1978-1982 average reported in Table 8 is used with the cultivar mix identified in Analysis I. This new base ozone-cultivar mix pairing is Analysis IV. Other annual ozone levels (from the 1978-1982 period) could have also been used to test the effect of base ozone assumptions on economic estimates. The average level was used because there was no consistent trend or pattern in the annual ozone levels when expressed at a state level. Thus, some regions displayed highest ozone levels (for the five year period) in

Table 7. Weibull model parameter estimates, by crop and cultivar combinations a/

Crop/Cultivar	Parameters			Degrees of Freedom
	α	σ	c	
Barley (Poco cv.)	1.988 (0.051)b/	0.205 (0.669)	4.278 (17.15)	21
Corn (Pioneer-3780 cv.)	12533 (323)	0.155 (0.004)	3.091 (0.461)	17
Corn (2 pooled cultivars)c/	--	0.158	3.530	--
Cotton (Acala SJ-2 cv.)	5351 (310)	0.092 (0.005)	2.530 (0.731)	21
Cotton (Stoneville-213 cv.)	3686 (140)	0.112 (0.004)	2.577 (0.416)	21
Cotton (2 pooled cultivars)d/	--	0.226	1.445	--
Grain Sorghum (Dekalb-28 cv.)	8137 (218)	0.296 (0.019)	2.217 (1.229)	17
Soybeans (Davis cv.-1981)	5593 (863)	0.128 (0.019)	0.872 (0.284)	43
Soybeans (all data) (16 pooled data sets)e/	--	0.165	1.303	--
Soybeans (Corn Belt) (5 pooled cultivars)f/	--	0.144	1.307	--
Soybeans (Southeast) (5 pooled cultivars)g/	--	0.144	1.576	--
Wheat, winter (Roland cv.)	5479 (312)	0.113 (0.005)	1.633 (0.288)	17
Wheat, winter (2 pooled cultivars)h/	--	0.146	2.235	--
Wheat, spring (4 pooled cultivars)i/	4.480 (0.200)	0.186 (0.040)	3.200 (1.860)	--

[a] The general form of the Weibull model is:

$$Y = \alpha \exp[(X/\sigma)^c] + \varepsilon$$

where Y is yield and X is the ozone dose in seasonal seven-hour per day mean concentration in ppm. The parameters are α, the hypothetical maximum yield at zero ozone concentration; σ, the ozone concentration when yield is 0.37; c, a dimensionless shape parameter (e.g., c=1 is the exponential loss function and larger c's imply less repsonse). If ε is zero, then yield goes to zero as ozone $\rightarrow\infty$.

[b] Values in parentheses are standard errors. Standard errors for pooled models are not reported in sources cited below.

[c] Includes Pioneer 3780 and PAG 397 cultivars.

[d] Includes Acala SJ-2, irrigated and dry cultivar experiments.

[e] Includes Amsoy, Corsoy 1980, 1983; Davis 1982, 1983; Essex, Forrest 1982, 1983 - irrigated and dry; Hodgson and Williams 1981, 1982 - irrigated and dry; and 1983 -irrigated and dry cultivar experiments.

[f] Includes Amsoy, Corsoy 1980, 1983(2) and Hodgson cultivar experiments.

[g] Includes Davis 1982, 1983; Essex and Forrest 1981, 1983(2) cultivar experiments.

[h] Includes Abe and Arthur 71 cultivars.

[i] Includes Blueboy II; Coker 47-27; Holly and Oasis cultivars.

SOURCE: Heck et al., 1984b, Tables 1 and 3; Heck et al., 1983, Table 2, and Kress and Miller, 1983. Response functions incorporating 1983 data (the pooled soybean models) are from W.W. Cure (personal communication).

years when other regions were below the five-year average. In the absence of any consistent pattern, the five year average was selected as a point of comparison with the 1980 values.

The only exception to this direct application of the Kriged seasonal data pertains to ozone levels used for winter wheat, which is grown in the fall through spring period when ozone levels are typically less than observed in the April-September period. To approximate these lower winter levels, the April values for each region are used as the base ozone levels for use with the winter wheat response functions. These April values may be slightly higher than ambient winter season averages. However, given that the most active growth period for winter wheat occurs in the spring, the use of April values for ozone is acceptable.

The second piece of ozone information needed to develop yield adjustments are the hypothetical ozone levels to be examined in the economic analysis. For the purposes of this assessment effort, these are identified as 10, 25, and 40 percent reductions in ozone from ambient (as portrayed in Table 8) and a 25 percent increase in ambient ozone. These adjustments in ambient ozone are portrayed in Appendix Table D.1 for each of the five years and for the 1978-1982 average concentrations. Each hypothetical ambient ozone level is then used in conjunction with the Weibull response functions for each crop to predict the yield changes associated with these changes in ambient ozone concentrations.

The 10 and 25 percent adjustments in ambient ozone are considered plausible changes, in that changes of this magnitude are encompassed in the temporal variability displayed in the five year ozone data set. Also, the 10 and 25 percent improvements in ozone levels are of policy importance in that these adjustments parallel changes in ambient ozone likely to be associated with alternative Federal secondary ambient air quality standards of 100 and 80 ppb (not to be exceeded more than once per year). Assuming the imposition of a more strict Federal standard, the ambient seasonal seven hour concentrations should decline. If one assumes a log-normal distribution of ozone events over the season, then achieving a hypothetical Federal hourly standard of 80 ppb would translate into a seasonal seven-hour average of about 40 ppb. Such an ambient ozone level is consistent with those achieved with the 25 percent ozone reduction scenario (see Appendix Table D.1). Similarly, the 25 percent ozone increase results in ozone levels somewhat similar to what would be realized if a Federal secondary standard of 140 ppb were just achieved.

The 40 percent ozone reduction is an extreme analysis in that such a reduction in ozone would bring actual ambient concentrations down to or below what is generally thought to be background or natural ozone levels (Heck et al., 1984a). Thus, the economic benefits measured in the 40 percent analysis may not be relevant from a policy standpoint. It does, however, represent the maximum benefits of ozone control, assuming all anthropogenic sources of ozone precursors could be controlled.

Table 8. Seasonal 7-hour average ozone levels by state, 1978-1982[a]

Year State	1978	1979	1980	1981	1982	1978-1982 Average
	------------------		(parts per billion)		------------------	
Alabama	50.47	41.22	46.98	47.28	50.43	47.3
Arizona	45.62	42.48	51.63	47.93	46.07	46.7
Arkansas	56.62	50.14	51.47	47.62	45.56	50.3
California	46.82	51.14	52.04	50.44	46.29	49.3
Colorado	50.36	51.32	50.92	48.10	50.42	50.2
Connecticut	45.50	49.50	58.83	51.00	51.33	51.2
Delaware	43.00	45.00	36.00	54.00	49.00	45.4
Florida	42.98	34.69	35.33	42.51	38.87	38.9
Georgia	54.65	43.40	46.82	45.87	45.65	47.3
Idaho	N.A.	51.00	45.71	47.60	47.88	38.4
Illinois	49.92	45.30	46.92	41.69	45.52	45.9
Indiana	48.58	39.87	46.72	45.10	47.33	45.5
Iowa	47.25	40.72	42.11	32.88	35.34	39.7
Kansas	47.53	43.76	45.47	40.98	41.62	43.9
Kentucky	48.73	39.10	44.88	39.16	45.68	43.5
Louisiana	43.25	35.14	42.22	41.94	39.78	40.5
Maine	42.82	37.66	34.98	31.41	35.57	36.5
Maryland	44.91	41.82	48.72	49.73	50.73	47.2
Massachusetts	41.23	44.17	46.83	44.92	44.25	44.3
Michigan	38.05	35.60	37.56	37.93	39.40	37.7
Minnesota	43.98	36.49	39.25	32.79	33.92	37.3
Mississippi	52.35	40.50	49.25	47.20	44.38	46.7
Missouri	52.55	48.51	49.20	37.78	40.24	45.7
Montana	34.00	49.43	45.00	46.00	46.17	44.1
Nebraska	49.03	42.30	45.17	38.10	33.45	41.6
Nevada	49.47	53.31	50.84	48.21	48.53	50.1
New Hampshire	42.25	40.75	42.58	34.58	37.50	39.5
New Jersey	42.10	43.60	53.50	50.30	51.30	48.2
New Mexico	49.96	47.90	45.87	48.40	47.02	47.8
New York	42.13	40.05	40.91	37.14	36.74	39.4

Table 8. (continued)

Year / State	1978	1979	1980	1981	1982	1978-1982 Average
	------------------		(parts per billion)		--------------------	
North Carolina	50.83	40.81	54.66	47.94	46.10	49.7
North Dakota	37.00	36.00	38.20	37.25	34.21	36.5
Ohio	45.98	38.42	42.77	41.04	43.88	42.4
Oklahoma	52.37	48.53	47.44	46.54	44.40	47.9
Oregon	27.32	30.11	32.06	35.20	38.18	32.6
Pennsylvania	43.65	38.31	45.11	38.20	40.85	41.2
Rhode Island	41.33	47.00	53.33	51.66	50.67	48.8
South Carolina	63.52	46.50	53.91	49.10	48.33	52.3
South Dakota	42.27	38.74	42.00	37.38	33.39	38.8
Tennessee	50.32	35.27	46.66	43.22	48.12	44.7
Texas	42.23	46.16	42.86	43.64	45.57	44.1
Utah	49.05	48.39	52.96	49.90	52.40	50.5
Vermont	43.07	42.86	43.14	35.36	37.29	40.3
Virginia	52.90	40.71	54.80	48.16	49.33	49.2
Washington	27.63	31.34	26.49	28.78	28.65	28.6
West Virginia	41.77	37.91	44.14	39.05	41.10	40.8
Wisconsin	45.81	43.59	40.46	38.19	38.55	41.3
Wyoming	46.31	50.75	47.56	48.83	49.71	48.6

Source: J. Reagan (1984) and 1982 NCLAN Annual Report (Heck et al., 1983).

[a] Averaging time is 0900 through 1600 hours, April through September.

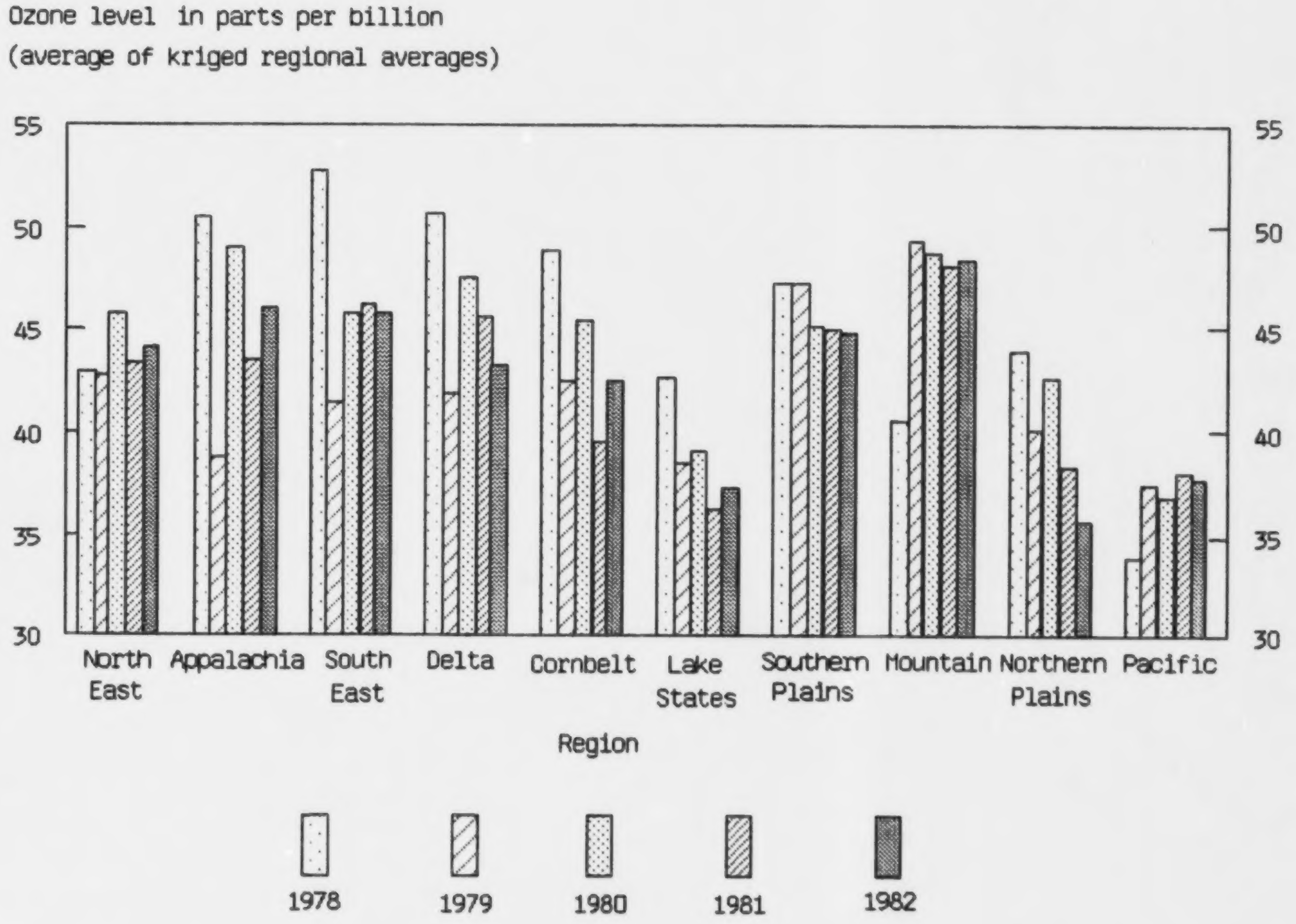


Figure 3. Ozone levels: 1978-1982 by region

Moisture Stress - Ozone Interactions

The NCLAN crop response functions presented in Table 7 provide the mechanism for quantifying the biological link between ambient ozone levels and crop yield response. In addition to providing this quantitative information about plant response for use in economic assessments, the NCLAN crop experiments also provide information of a more qualitative nature concerning environmental stresses that may interact with ozone. Specifically, the possible interactive effects of ozone with water stress and with other pollutants (SO_2) have been addressed in a few experiments (see, for example, Heck et al., 1983). While these experiments and the resultant data are not sufficient to document and quantify such interactions adequately, they provide some plausible grounds for modifying and perhaps bounding the economic estimates generated from the response information in Table 7.

The information on interactive stresses can suggest whether the NCLAN response functions (which are estimated holding other inputs and stresses constant at "normal" or ambient levels) over- or under-state the real or "true" effect of ozone on commercially grown crops. For moisture stress, several NCLAN experiments conducted in 1982 and 1983 suggest that water-stressed plants are less prone to suffer ozone yield reductions than fully watered plants. (The one synergistic observation noted earlier is the exception.) Ozone yield effects for water-stressed plants are up to 30 percent less than well-watered plants for these experiments. Thus, data generated under fully watered or optimal water conditions may overstate potential ozone yield depression when compared with crops grown under less than optimal water conditions. Such an expectation is consistent with general production theory concepts as used in economic analysis; namely that the marginal product (or effect) of inputs such as water will be greater in an unconstrained environment. This manifestation of the Le Chatlier principal means that when all inputs are set at physical product maximizing levels, the marginal effect on yields will be greater than at levels observed under suboptimal but more realistic production conditions (Silberberg, 1973).

The NCLAN requirements on drought stress have focused on only two crops, cotton and soybeans. While the preliminary cotton results demonstrate that drought stress reduces ozone effects, the soybean results are ambiguous, in that one experiment demonstrated that drought stress increased yield response to ozone at near ambient levels. As noted earlier, however, this contradiction with the cotton and other soybean results is not yet replicated and hence the bulk of the available evidence points to an antagonistic relationship between drought stress and ozone-yield effects.

In addition to conducting ozone-water stress experiments, NCLAN has constructed a general crop model designed to estimate the influence of drought on ozone-caused crop loss (King and Snow, 1984). The model attempts to estimate both the direct influence of water stress on the ozone damage process and the influence of ozone-caused damagef on subsequent crop water use. Preliminary ozone-water stress simulations (King, personal communication) provide the basis of a moisture stress analysis which is defined in Analysis V. The crop model and associated assumptions used to derive the adjustment factors is described in Appendix C. The resulting adjustment curve is presented in Figure 4.

The crop model estimates are used to compare the potential difference in ozone effects between non-irrigated and adequately watered crops. This differential for varying degrees of water stress is then used to modify the well-watered yield adjustments reported in Appendix Tables D.3 to D.11 (representing the pooled responses used in Analysis I). The plausibility of the adjustment factors in Figure 4 is supported by the general results of the few NCLAN experiments that compare well-watered and drought stressed ozone responses. Note that the adjustment factors are expressed in terms of the yield reductions due to moisture stress. Thus two types of information are needed to incorporate the effects of drought stress pictured in Figure 4 into the ozone assessment. First, information on the spatial distribution of rainfall in the U.S. is required to gauge the extent and severity of drought for a particular growing season. Given that summer rainfall patterns associated with continental climate zones tend to vary even within a relatively small geographical area, detailed spatial resolution in rainfall data is desirable. In this analysis, rainfall as measured on a state-by-state basis for 1980 served to suggest the potential for drought stress. Specifically, the departure from normal July rainfall for each state, as reported in the Weekly Weather and Crop Summary (USDC, NOAA, 1980), is used to define potential crop drought stress. The use of July deviations in rainfall as a drought measure is based on the results of Huff and Neill (1980, 1982) which demonstrate that July rainfall is the most critical environmental determinant of seasonal yields for corn and soybeans. These July rainfall departures are reported in Table 9.

A second piece of information is needed to translate the deviations from normal July rainfall into drought stress yield reductions. This information is derived from studies by Thompson (1969, 1970) for corn and soybean yields in the Corn Belt. Specifically, regression equations are derived from Thompson's results that predict percent yield reduction for these crops associated with deviations in July precipatation. The effects across the two crops are averaged to arrive at a surrogate crop drought stress yield reduction. This reduction is then used in combination with the ozone-water stress trade-off curve depicted in Figure 4 to obtain an adjustment factor to be applied to the fully watered NCLAN response functions as used in the previous analyses. These are reported in the last column of Table 9.

A number of points need to be made concerning this procedure and the resultant adjustment factors. First, the July data used here are statewide. To the extent that drought may be more localized, these averages introduced potential biases that can only be addressed with detailed rainfall data. Second, rainfall in months other than July obviously influence yields. The extent of these other rainfall influences is not analyzed. Third, the drought stress procedure attempts to key on those states where crops typically are not irrigated. Thus, only states in the eastern half of the U.S. are included (non-irrigated wheat production in the western U.S. was not included). Some states in this set, however, do feature a percentage of irrigated acreage. An attempt was made to account for states with both irrigated and non-irrigated acreage (Nebraska, Oklahoma, Kansas, Texas and Arkansas) by reducing the

Table 9. July drought, yield reductions and moisture stress adjustment factors, by state

State[a]	Departure from normal July precipitation[b]	Percent yield reduction from normal due to moisture stress[c]			Moisture stress adjustment factor [d]
		Soybeans	Corn	Average	
	(cm)				
Alabama	6.17	14.0	27.7	20.9	.65
Arkansas	5.33	10.9	25.0	18.0	.68
Connecticut	0	0	0	0	1.0
Florida	2.06	3.8	16.5	10.1	.74
Georgia	8.26	18.5	35.0	26.8	.61
Illinois	2.74	5.0	17.9	11.5	.72
Indiana	0.25	1.0	12.6	6.8	.87
Iowa	3.43	6.6	19.7	13.2	.70
Kansas	3.20	5.0	13.0	9.0	.77
Kentucky	2.79	5.2	18.1	11.7	.72
Louisiana	0	0	0	0	1.0
Maine	0	0	0	0	1.0
Maryland	2.35	4.5	16.8	10.6	.73
Massachusetts	2.03	4.0	16.2	10.1	.74
Michigan	0	0	0	0	1.0
Minnesota	3.05	5.8	18.8	12.3	.72
Mississippi	3.30	6.3	19.4	12.9	.70
Missouri	4.70	9.5	23.3	16.4	.68
Nebraska	4.88	5.0	12.5	8.8	.76
New Hampshire	1.78	3.3	15.6	9.5	.75
New Jersey	5.21	10.8	24.8	17.8	.68
New York	0.89	2.0	13.6	7.8	.80
North Carolina	6.15	13.0	27.7	20.4	.66
North Dakota	2.46	4.5	17.2	10.9	.73
Ohio	0	0	0	0	1.0
Oklahoma	4.06	8.1	21.5	14.8	.69
Pennsylvania	0	0	0	0	1.0
Rhode Island	0	0	0	0	1.0
South Carolina	2.54	4.7	17.5	11.1	.73

Table 9. (continued)

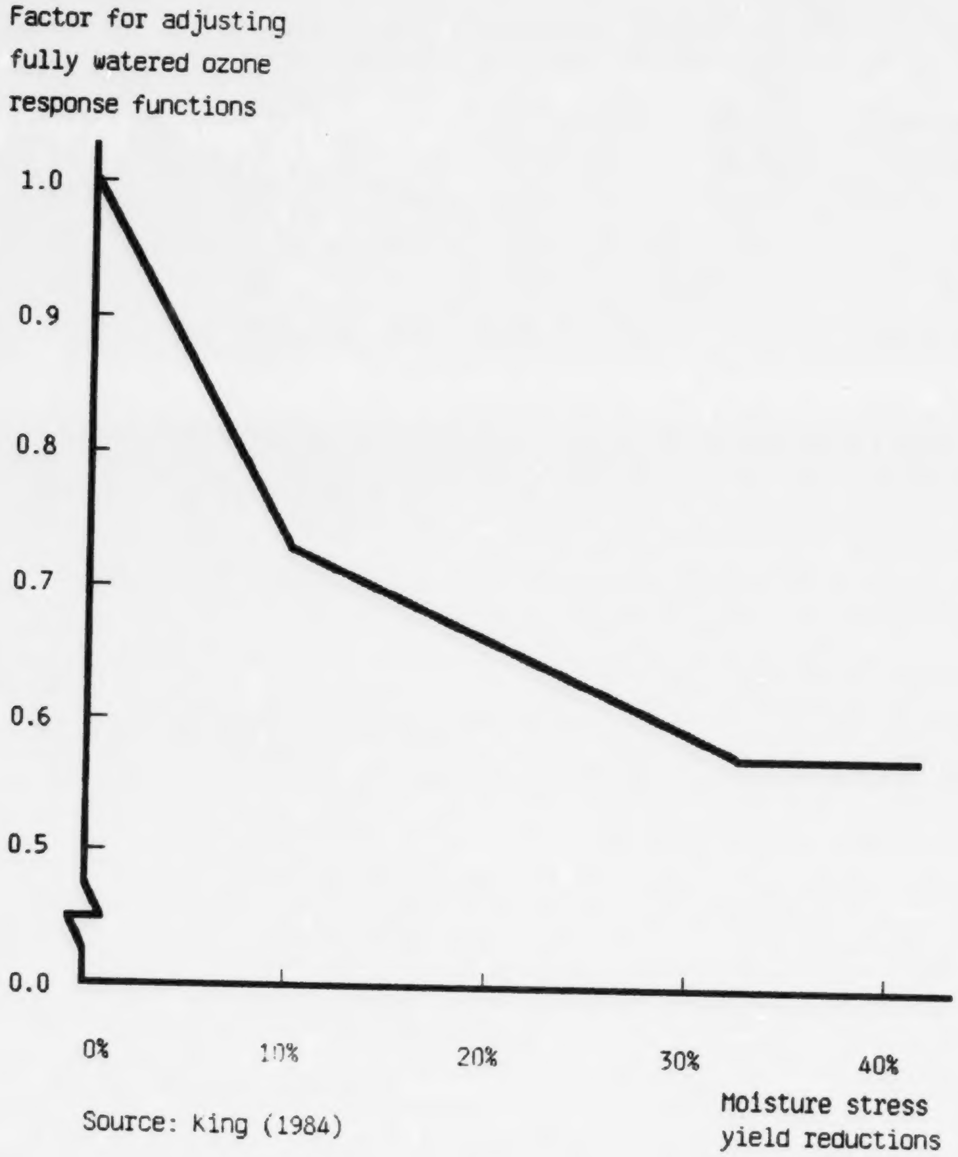
State[a]	Departure from normal July precipitation[b]	Percent yield reduction from normal due to moisture stress[c]			Moisture stress adjustment factor c/
		Soybeans	Corn	Average	
	(cm)				
South Dakota	1.40	2.5	14.7	8.6	.78
Tennessee	1.02	2.0	13.9	8.0	.80
Texas	6.40	12.5	24.5	18.5	.66
Vermont	0	0	0	0	1.0
Virginia	0	0	0	0	1.0
West Virginia	0	0	0	0	1.0
Wisconsin	3.80	7.4	20.8	14.1	.69

[a] Includes those states where crop production occurs primarily under non-irrigated conditions. For Nebraska, Kansas, Oklahoma, and Texas, the adjustment factors are weighted to reflect a percentage of irrigated cropland that would not experience drought stress.

[b] Includes only departures below normal precipitation. A zero value corresponds to normal or above normal rainfall for July.

[c] Percent yield reductions estimated from quadratic yield regressions derived by Thompson (1969, 1970). The estimated reduction for corn assumes that a certain yield reduction is associated with normal July rainfall. The soybean reduction is based on the assumption that no yield reduction occurs for normal or above normal July rainfall.

[d] Adjustments derived from Figure 4.



Source: King (1984)

Figure 4. The modelled effect of moisture stress on predicted ozone yield reductions

drought effect by the percentage of irrigated acreage. Still, it is likely that some irrigated acreage in other states may not be reflected in the adjustment factors. This again may bias the adjustment factors for such states. Fourth, the adjustment factor is based on the averaged response of corn and soybeans. It is assumed that this drought-yield relationship holds for all the crops in the assessment. While corn and soybeans are the dominant crops in the assessment, the use of this average may not accurately portray the response of other crops. Finally, the curve depicted in Figure 4 is based on a newly developed model of the drought-ozone interaction as it affects crops. While the parameters and data underlying the model appear plausible and the results conform to the available NCLAN drought stress experiments, the application of the model should be considered tentative. Thus, the results of the moisture stress-ozone analysis captured in Analysis V need to be used with caution. As noted above, the primary purpose of the analysis is to suggest the importance of accounting for moisture-stress and other interactions in economic assessments of environmental stress.

VI RESULTS AND IMPLICATIONS

An empirical model of an economic sector as diverse and dynamic as U.S. agriculture not only requires a conceptual framework capable of addressing the important economic dimensions, but also substantial physical and economic data to implement the model and an algorithm for solving the analytical problem inherent in the conceptual model specification. The conceptual model, data and solution procedure used in this assessment have been described earlier. Given the number of production activities, regions and final products, the dimensions of the analytical problem are substantial. Specifically, the 55 production regions, ten primary crop commodities, 16 secondary crop and livestock commodities and the consumption-export balance considerations for each give rise to a matrix with approximately 200 rows and 1500 columns. The problem is then solved on a Cyber 170 computer using the MINOS software package.

The aggregate model is a revision of the Baumes model which has been used in a number of previous studies (Baumes, 1978; Burton, 1982; House, 1983; and Adams and McCarl, 1984). These previous solutions were considered adequate representations of agricultural conditions, as established by comparison of model predictions of equilibrium prices and quantities with actual values for a given time period. However, the current assessment reflects model modifications and data that differ from earlier analyses. Thus, the plausibility of the results from the current model and data need to be established.

The plausibility of the results generated by this or any conditional normative model rest partially on the validity of the base model. The resemblance of base model outputs to actual prices and production (as reported in USDA, Agricultural Statistics, 1981) is one means of establishing the credibility of the model. Close correspondence between actual and predicted values of key endogenous variables can then lend support to the validity of subsequent changes in economic values arising in the ozone-yield reduction evaluations.

This section first reports the results of the base model and compares these outputs with 1980 values. Specifically, equilibrium prices and quantities, objective function values (welfare measures) and regional production patterns are compared. Each of these features has direct importance in demonstrating the plausibility of the model as well as evaluating the economic effects of ozone. The results and implications of the five major ozone-yield evaluations (Analyses I through V) as measured against the base situation are then presented. Additional information, such as input use and consumer surplus estimates by commodity, is contained in the model solutions. While not discussed here, the validity of these latter estimates is linked to the price and quantity relationships that underlie the model solution process. Establishing the plausibility of these key model variables is thus sufficient to document the performance of the overall model.

Base Model Results

The economic model applied to the ozone assessment problem simulates a long-run equilibrium. To the extent that agriculture is usually in a state of disequilibrium with respect to production and prices in any given year, exact correspondence between a short-run situation, even with parameters and data calibrated to that situation, is not expected. What is expected, however, is for the model to predict the general magnitudes of important variables, e.g., prices. More importantly, the model should consistently account for and predict directions in the movements of these variables when the model is perturbed. This is crucial for the assessment of potential effects arising from technical or policy changes, since it is the direction of change in these values, perhaps more than the values themselves, that is of relevance in gauging policy efficiency. These same considerations apply to the assessment of environmental change, such as the potential alteration in ozone levels addressed here.

To demonstrate the performance of a general equilibrium model of agriculture, the model outputs of primary concern are predicted prices and quantities of the included crops and commodities. The level of these variables represent the optimal solution to the mathematical problem contained in the conceptual model. Since changes in ozone levels will alter crop yields (from actual 1980 yields used in the base model) and relative profitability in the subsequent analyses, it is important that the base model prices and quantities provide a reasonable portrayal of commodity mixes and prices. The actual and model prices and quantities in 1980 for 12 crop commodities are presented in Table 10.

As is evident from Table 10, the model predicts equilibrium prices that are generally within five percent or less of the actual prices observed in 1980. For most crops (11 of the 12) the model price levels are equal to or slightly higher than actual. In terms of quantities, the model results are within 10 percent of actual for most crops (the exceptions are sorghum, 17 percent, and silage, 20 percent). For 7 of the 12 commodities, model production exceeds actual. The relatively large oversupply of sorghum and silage

Table 10. Actual and model 1980 prices and quantities for primary crops and commodities

Commodity	1980 Prices Model	1980 Prices Actual	1980 Quantities Model	1980 Quantities Actual
	$/unit[a]		(million units)	
Cotton	366.72	358.00	17.45	15.65
Corn	3.25	3.11	7,339.85	6,645.84
Soybeans	7.74	7.57	1,778.07	1,792.06
Wheat	3.71	3.91	2,633.94	2,374.31
Sorghum	3.00	2.94	700.88	579.20
Rice	12.79	12.80	164.78	146.15
Barley	2.91	2.85	335.50	360.96
Oats	1.93	1.79	472.91	458.26
Silage	19.46	NA	91.24	110.97
Hay	70.90	71.00	141.58	131.03
Soybean Meal	0.11	0.11	46,180.80	50,624.00
Soybean Oil	0.24	0.23	10,755.81	11,270.00

[a] Units are as follows: 500 pound bales for cotton; bushels for corn, soybeans, wheat, barley, oats, and sorghum; hundredweight for rice; tons for hay and silage; pounds for soybean meal and oil.

depicted in the base model is due to the presence of a drought in the Corn Belt and Southern Plains regions in 1980 that lowered yields which then lead to a shift of corn planted for grain into silage use. However, when the silage and sorghum quantities are compared with 1979 and 1981 actual levels, the model supply projections are within 3 percent. Given the long-run nature of the assessment model, sharp divergences from historical levels in a given year are difficult to simulate.

A similar comparison of livestock and livestock products is provided in Table 11. The inclusion of a livestock component is an important feature of an agricultural assessment, since livestock account for approximately 50 percent of total economic activity in agriculture. Further, most of the grain and oil seed production in the U.S. is produced for livestock consumption, not directly for consumers. A model of agriculture should thus represent the consumption link between primary commodities (e.g., corn for grain), intermediate products (e.g., oil or meal) and final products (e.g., fresh meat products). Reductions in corn or soybean yields due to ozone can then be traced through the feed grain-oil seed-livestock balance to the final consumer.

The comparison in Table 11 indicates that model and actual livestock prices and quantities display strong similarities. Specifically, model prices fall within 3 percent of actual, while quantities are again within 10 percent of actual levels observed in 1980. Overall then, the model prices and quantities for both crop and livestock commodities appear to capture the relative magnitudes of equilibrium prices and quantities observed in recent years.

The prices and quantities endogenously derived in the model are those that maximize the model objective function. As noted in the methodology discussion and Appendix A, optimizing the objective function is analogous to maximizing the sum of consumers' and producers' surplus (as measured through commodity and factor markets). While it is important to establish the plausibility of the equilibrium prices and quantities, it is the change in objective function value that is used to measure the economic effects of ozone on agriculture. Specifically, changes in the objective function value (economic surplus) between the base case and the ozone analyses represent the social benefits or costs of changes in ozone levels. Further, comparisons of shifts in consumers' and producers' relative shares of the objective function across different analyses can suggest the equity consequences of such changes. For these reasons, the objective function value assumes major importance in the assessment.

The objective function (or total social benefits) value for the base solution are as follows:

Consumers' Surplus:	$114.96 billion
Producers' Surplus:	26.02 billion
Total Social Benefit:	$140.98 billion

Table 11. Actual and model 1980 prices and quantities for dairy and livestock products

Product	1980 Prices		1980 Quantities	
	Model	Actual[a]	Model	Actual[a]
	$/unit		million units	
Milk	12.95	13.00	1,282.24	1,286.20
Pork	139.00	139.50	141.68	165.77
Fed Beef	237.50	237.60	138.20	159.36
Veal	310.30	309.50	3.66	4.11
Non-Fed Beef	150.20	149.76	64.40	73.22

Source: USDA, Statistical Reporting Service, Statistical Bulletin 552.

[a] Units are hundredweight. Meat prices are average retail prices for finished meat products.

These values are measured in 1980 dollars and capture the economic surpluses associated with the production and consumption (domestic and foreign) of the major crop and livestock commodities in the U.S. The reasonableness or validity of these estimates is not as easily demonstrated as prices and quantities, given that actual measures of such welfare effects are not available. However, some information, such as the farm gate value of these commodities, can be used to establish reasonableness. According to USDA Agricultural Statistics, the 1980 farm value of the crop and livestock commodities included in the model was approximately $111 billion ($60 billion for crops, $51 billion for livestock products). The comparable gross farm level revenue calculated in the model is $107 billion, an error of less than four percent. This indicates that the demand specification underlying the prices and quantities is realistic, which provides some evidence that the associated surplus values, measured as integrals under those curves, are also reasonable. Ultimately, however, the validity of the objective function value is based on the endogenously derived prices and quantities which give rise to the objective function values. The credibility of these values has already been established.

Modeling the U.S. agricultural sector is an exercise in comparative advantage in that the historical regional mix and acreages of crops reflects that region's resource endowments and proximity to markets. While particular regions normally specialize in the production of given crops because of comparative advantage, market shares will change due to weather and other environmental changes. This is one rationalization for the use of spatial equilibrium models in assessing the effects of pervasive induced changes on agriculture, such as those associated with technical change or Federal policies. Regional definition is an important feature of the model, as it allows for the comparison of differential effects across regions in the face of environmental change. The capacity of a region to respond to changes in crop yields due to ozone or technical change by adjusting acreage or switching crops will have an effect on the economic consequences experienced by that region. Given different resource endowments and ambient ozone levels, this implies that the economic effects of changes in ozone levels will not be uniform across all regions. Like the tradeoff between producer and consumer well-being, distributional effects in regional welfare are another dimension of the equity issue in regulatory policy.

As noted above, the aggregate crop production levels reported in Tables 10 and 11 are close to actual production. However, the performance of sector models of the type used here frequently suffers when regional or finer levels of disaggregation are examined. To ensure that the spatial dimensions of the model are consistent with actual patterns at a less aggregated level, the cropped acreage predicted by the model are compared with actual acreages for the ten major USDA production regions (Figure 5). These values are presented in Table 12. As with the other model outputs, there is a close correspondence between model regional acreages and actual. The model results are slightly below actual national acreage of all crops. This is due to the exclusion of some minor specialty crops from the model specification. Despite a slight understatement nationally, the base model acreages are quite similar to the regional production patterns realized in the U.S. in 1980.

This evaluation of the model indicates that the central features of the 1980 base solution accurately simulate the actual environment for that time period. The comparison of equilibrium prices and quantities, revenues and regional acreage responses serve to validate the model and establish the base analysis as a suitable benchmark to gauge the economic effects of the ozone-yield perturbations. The next section presents the results of applying the five ozone-yield reduction analyses to the base model. Analysis I through V, each with the four ambient ozone level adjustments, are presented and discussed. The key features to be evaluated are the changes in net social benefits (between the base value and each ozone assumption), the changes in crop prices and the regional effects.

Analysis I

As summarized previously (in Table 6), Analysis I uses pooled response functions based on all statistically homogeneous experiments (across cultivars and years) of corn, soybean, and wheat (spring and winter). In addition, the single cultivars of barley, sorghum, and cotton (irrigated and dry) are used. A surrogate hay response, based on the average yield response of the six other crops, is also included and used to perform "with" and "without" hay adjustment analyses; i.e., in one set of runs, hay yields are held constant through

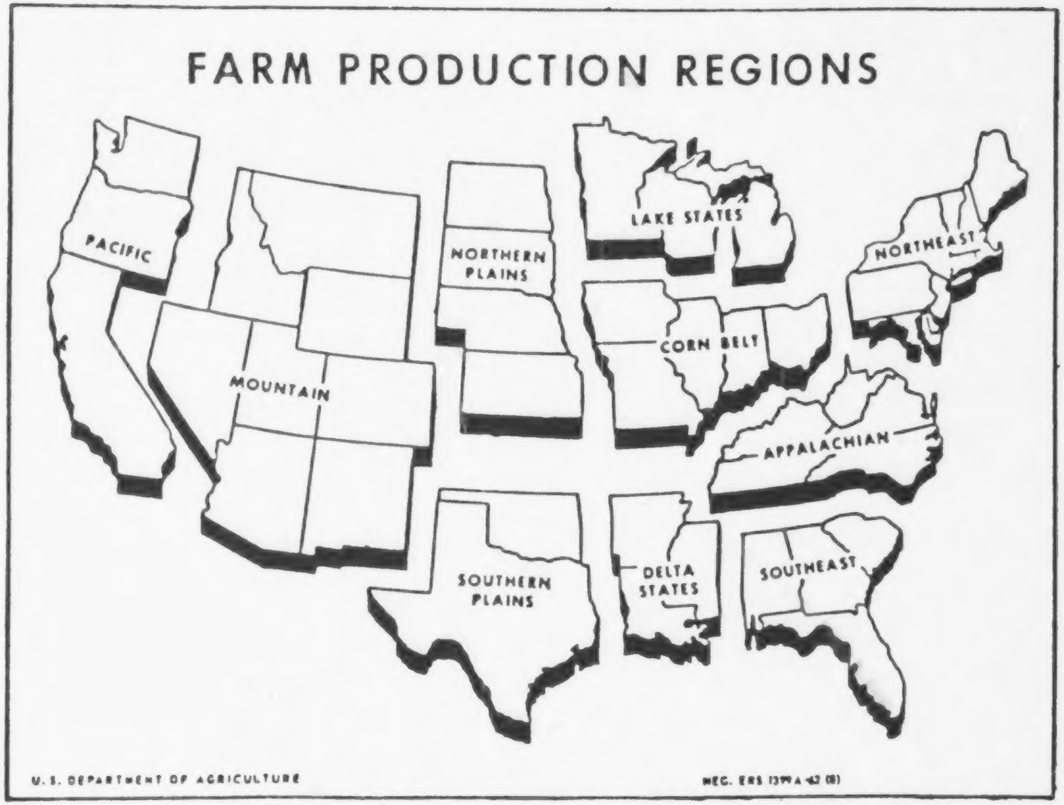

FARM PRODUCTION REGIONS
PACIFIC
MOUNTAIN
NORTHERN PLAINS
SOUTHERN PLAINS
LAKE STATES
CORN BELT
DELTA STATES
NORTHEAST
APPALACHIAN
SOUTHEAST
U.S. DEPARTMENT OF AGRICULTURE
NEG. ERS 1399A-62 (8)

Figure 5. Farm production regions in the United States.
Source: USDA ERS.

Table 12. Model and actual 1980 regional and total U.S. cropped acreages[a]

Region	Acreage Model	 Actual
	1,000 Acres	
Northeast	13,157	12,949
Lake States	39,637	37,770
Corn Belt	84,740	90,064
Northern Plains	75,533	77,956
Appalachian	20,439	20,797
Southeast	15,234	14,944
Delta	20,938	22,078
Southern Plains	35,779	37,805
Mountain	22,709	27,393
Pacific	11,938	14,728
Total	340,104	356,484

Source: USDA, Agricultural Statistics, 1981.

[a] Cropped acreage refers to land planted to crops. It excludes pasture and grazing land.

the ozone changes; in the other analysis hay yields change with changing ozone. The ozone assumptions are 10, 25, and 40 percent reductions and a 25 percent increase in ambient levels, as measured by the 1980 seasonal seven-hour acreage in each of the 55 production regions. Together, these ozone levels and cultivar response functions (as defined earlier) give rise to the yield adjustment coefficients that are used to modify the base model yields (reported in Appendix D). The resulting changes in objective function values (from the base case) define the economic benefits or costs to society for each ozone adjustment.

The model output of greatest interest is the objective function value generated under each model solution. The values of the objective function for Analysis I are presented in Table 13. The table includes both the "with" and "without" hay yield adjustment evaluations. Also presented are the changes in objective function values from the base case, as well as producer and consumer surplus components of each total. This table thus provides estimates of the preliminary national economic consequences of ozone on agriculture utilizing NCLAN data through 1983. As such, these estimates satisfy one of the major objectives of the NCLAN program.

The economic effects reported in Table 13 are estimates of the changes in consumers' plus producers' surplus of those involved with the agricultural sector, as stimulated by a change in ozone. This quantity is equivalent to the sum of the agricultural sector-related income lost or gained by producers and consumers as a consequence of air pollution changes. The term "benefit" is used to indicate a gain in agriculturally-related consumers' and producers' surplus. Similarily "costs" (negative benefits) will be used to indicate losses. The calculation of consumers' and producers' surplus does not include compliance costs required to achieve the alternative ozone concentrations evaluated in this analysis. Also, the effect of ozone changes on non-agricultural goods and services are not evaluated. Thus, the benefits reported here should not necessarily be interpreted as net benefits to society associated with the ozone changes evaluated in this study.

A considerable amount of information can be gleaned from Table 13. First, the general magnitudes of the changes in economic surplus are noteworthy as they represent the benefits to society from alternative ozone levels under the assumptions of this assessment. Specifically, the simulated improvements in air quality (reductions in ozone from 1980 ambient levels) result in substantial annual benefits to society. The benefits of a 10 percent reduction in rural ozone range from $669 to $756 million, depending on whether hay yields are allowed to vary in the assessment. A 25 percent reduction in ozone produces benefits of $1.712 to $1.937 billion across the same hay assumptions. The more extreme 40 percent reduction in ozone would yield benefits of $2.52 to $2.86 billion. Finally, an increase in ozone levels (air quality degradation) by 25 percent produces a cost (negative benefit) to society of approximately $2.10 to $2.36 billion. All values are annual equivalents measured in 1980 dollars and exclude any consumption or production subsidies not directly embedded in the 1980 data.

The economic estimates associated with the four ozone adjustments amount to changes of approximately 1.3, 3.2, 4.6, and -4.0 percent in the gross farm value of the included crops. As a percentage change of the objective function values, the estimates are substantially less (0.5, 1.4, 2.0 and -1.7) percent, respectively. These changes are triggered by corresponding average yield changes (for the NCLAN crops) of 1.1, 2.5, 3.8, and -3.0 percent. Thus, the economic effects tend to be substantially less than the original physical effect suggested by the response functions. This observation is expected, given the general equilibrium nature of the economic model that allows for compensatory production, price and input adjustments. This relationship between physical effects and economic consequences is also consistent with results reported by other researchers (e.g., Adams et al., 1982, Howitt et al., 1984).

The importance of including a hay response can be partially addressed by examining the numbers in Table 13. Specifically, the difference between the two analyses is the approximately 13 percent higher benefits estimates when hay yields are assumed to vary (as the average of other NCLAN crops). This translates into differences of over $300 million in the extreme ozone changes. While the hay yield adjustments used in the "with hay" analysis are a surrogate response, they are similar to the results of Oshima et al. (1976) that indicate a moderate sensitivity for hay (alfalfa). Thus, the inclusion of these hay adjustments may provide a reasonable approximation of the effects of ozone on hay. Current NCLAN experiments are producing a series of hay response estimates that should refine future assessments.

Table 13. Annual economic effects of ozone in 1980 dollars: Analysis I

Ozone Assumption	Economic surplus			Changes in economic surplus		
	Producer Surplus	Consumer Surplus	Total Surplus	Producer Surplus	Consumer Surplus	Total Surplus
	---------- $ billion	----------	----------	----------	----------	----------
Without Hay Adjustment						
Base	26.015	114.957	140.971	---	---	---
10% Reduction	26.250	115.390	141.640	0.235	0.433	0.669
25% Reduction	26.567	116.116	142.683	0.552	1.159	1.712
40% Reduction	26.788	116.701	143.489	0.773	1.744	2.518
25% Increase	25.413	113.462	138.875	-0.607	-1.495	-2.096
With Hay Adjustment						
Base	26.015	114.957	140.971	---	---	---
10% Reduction	26.337	115.389	141.727	0.322	0.432	0.756
25% Reduction	26.807	116.101	142.908	0.792	1.144	1.937
40% Reduction	27.271	116.559	143.830	1.256	1.602	2.859
25% Increase	25.122	113.486	138.608	-0.893	-1.471	-2.363

Another aspect of Table 13 includes the distributional effects across producers and consumers. As is evident, both producers and consumers share in these gains from increased supply. That consumers benefit from falling prices is an expected outcome. In absolute terms, consumers benefit more than producers i.e., over 60 percent of the gains accrue to consumers in most analyses. However, the observation that there are aggregate gains to producers with increased supplies is not generally expected, given slightly inelastic demands for most domestic commodities and a mix of elasticities for export markets.

The change (increase) in producer surplus resulting from an increase in supply is due to the complex interaction of the demand and supply relationships within the model. As noted, domestic and foreign demand is characterized by varying elasticities (including elastic responses for some exports). Further, it is the change in intercept and slope of the supply curve that partially determines net changes in producer surplus (i.e., the shifts in supply within the model are not always characterized by parallel shifts). In addition, primary (e.g., feed grains) and intermediate (e.g., livestock) commodities are included in the model, with corresponding derived demand implications vis a vis producers effects. Under these conditions, increases in producer surplus with increased supply are realized. Given the open nature of the economy in the model, it should also be noted that the analysis and results are based on the assumption that changes in ozone standards within the U.S. will not affect supplies in other exporting or importing countries. While some "spillover" of ozone changes may occur in southern Canadian wheat-producing regions, the meteorology of ozone formation and transport suggests that transboundary effects should be minimal, particularly with respect to transcontinental effects. Note also that ozone levels in the Northern Plains region of the U.S., a major wheat producing region, are relatively low compared to the Corn Belt and are unlikely to experience substantial ambient ozone due to changes in Federal standards. While no data are available on ozone levels in southern Canadian wheat producing regions, it is likely that ambient ozone concentrations in that area are also low.

Before proceeding to discuss other economic effects associated with Analysis I, the above economic estimates need to be placed in perspective. The 10 and 25 percent changes in ambient ozone levels are plausible changes, in that temporal variation of this magnitude are observed in the seasonal averages over the periods 1978-1982. However, the 40 percent reduction in ambient levels is approaching what some researchers suggest to be background or natural levels (Heck et al., 1984a). While the attainment of such a change may not be feasible, the benefits value imputed to this level of control are an estimate of the total economic consequences of all anthroprogenic ozone.

The 25 percent ozone reductions can also serve as a useful comparison with some recent economic estimates derived by other researchers, given that it closely simulates the ozone standards or levels used in these recent national assessments. Specifically, recent national analyses by Kopp et al. (1983) and Adams et al. (1984) use NCLAN data to derive yield adjustments. In the Kopp et al. analysis, improvement in air quality from the present ozone secondary standard of 120 ppb hourly maximum (not to be exceeded more than once per year) to a 80 ppb standard are estimated to result in benefits to society of approximately $1.10 billion. Such an assumed improvement in ambient levels is thus close to the 25 percent ozone reduction alternative in this study, assuming a log-normal distribution of ozone events. The Kopp et al. analysis does not include hay, sorghum, barley or livestock. Empirically it is perhaps closest to the $1.71 billion generated in the "without hay" analysis presented in Table 13. The difference in benefits recorded in the present study ($1.71 vs. $1.10 billion) may be due to more complete crop coverage, inclusion of an endogenous livestock sector and use of more recent NCLAN data (through 1983) in the present study. Also, the assessment methodologies differ, particularly with respect to the aggregation of regional supply and the regional adjustment process to ozone-induced supply shifts.

The Adams et al. study uses a comparable 25 percent ozone reduction and estimates the benefits from increased yields of corn, cotton, soybeans and wheat to be approximately $2.4 billion. The higher value in that study is due to use of higher ambient levels (uses the upper bound of regional ozone levels for 1980), the use of national supply functions for each crop (no micro detail) and a different benefits calculation procedure. The present study appears to overcome some conceptual and empirical shortcomings of these previous national assessments that use NCLAN data. The relative positioning of the estimates (higher than Kopp et al., lower than Adams et al.) seems consistent with the respective model structures and empirical focus.

Other dimensions of the model solutions in Analysis I are important to further assess the economic effects of these ozone levels. The changes in welfare across producers and consumers reported in Table 13 are an aggregate measure of distributional effects. Another distributional aspect is the relationship between domestic and foreign consumers of the commodities in the model. To examine this latter type of distributional effect, Table 14 presents a comparison of the consumer surpluses accruing to domestic and export use of the commodities. As the table indicates, the majority of the total consumer surplus arises from domestic consumption. This is because domestic use of the aggregate of these commodities is much greater than quantities exported. However, when the changes in consumer surplus associated with the increment in supply due to ozone are calculated, the gain through export markets is greater. This implies that the benefits of increases in supplies (beyond historical averages) of these commodities will accrue to foreign consumers. While domestic consumers may benefit from reduced prices due to increased supplies, the benefits to foreign consumers (and their intermediaries in the U.S.) are also substantial.

To understand how the changes in supply affect domestic prices and hence, consumer well-being, the prices of selected primary commodities and livestock products are presented in Table 15. The primary commodities in the table are those for which yields were adjusted in the ozone analysis. They are also ones that are used primarily as feedgrain or feed concentrate (protein supplement). The livestock commodities are final products consumed directly by the consumer as fresh meat. As is evident from the table, reductions in ozone have a differential effect on prices. For example, soybeans and to a lesser extent, wheat, show rather dramatic changes in equilibrium prices due to increases in yield (supply). This is due to their relative sensitivity to ozone, which results in large increases in supply relative to the much more ozone resistant crops, such as barley and sorghum, which have very limited supply increases, even at large ozone reductions.

On the livestock side, poultry and pork show the greatest price changes associated with the slight increases in supply of feedgrain under the ozone analysis. Milk also shows a modest change in price, consistent with the increase or decrease in feedgrain supplies in each analyses. Fed beef prices do not change much, showing only a limited price change at the more extreme ozone levels. The greater sensitivity of pork and poultry prices is due to the percent that feed contributes to total product value. Nearly the entire marketable product of pork and poultry is produced during the feed grain and concentrate feeding phase. Further, this feeding phase tends to be for a relatively short period (approximately thirty days for broilers). Conversely, less than half of the total marketable weight of beef is produced under the finishing or grain-feeding phase, with the bulk of body weight gain arising from consumption of roughage or pasture. As a result, feedgrains make up about 95 percent of the total variable cost of poultry and 80 percent for pork. For fed cattle, feedgrains are less than 40 percent (USDA, 1983).

Table 14. Effect of ozone on distribution of consumer surplus between domestic and export markets

	Consumer Surplus			Change in Consumer Surplus		
Ozone Assumption	Domestic	Export	Total	Domestic	Export	Total
Base Case (1980)	100.940	14.016	114.956	---	---	---
10% Reduction	101.059	14.330	115.389	0.119	0.314	0.433
25% Reduction	101.383	14.717	116.101	0.443	0.701	1.145
40% Reduction	101.516	15.043	116.559	0.576	1.027	1.603
25% Increase	100.296	13.189	113.486	-0.644	-0.827	-1.470

Table 15. Effect of ozone on prices of selected feedgrain, oil seed and livestock commodities

Commodity	Units	Base	Ozone Assumption 10% Ozone Reduction	25% Ozone Reduction	40% Ozone Reduction	25% Ozone Increase
			-------------------	$ per unit	-------------------	
Crops						
Corn	bu.	3.25	3.25	3.24	3.24	3.27
Soybeans	bu.	7.74	7.60	7.35	7.14	8.24
Wheat	bu.	3.71	3.60	3.54	3.46	3.88
Barley	bu.	2.91	2.91	2.91	2.96	2.91
Sorghum	bu.	3.00	3.01	3.00	3.00	3.02
Bean Oil	lb.	0.24	0.23	0.22	0.21	0.29
Livestock						
Poultry	cwt.	103.09	102.90	102.30	102.00	103.45
Fed Beef	cwt.	237.57	237.55	237.55	237.54	237.60
Pork	cwt.	139.15	139.09	138.52	138.49	139.50
Milk	cwt.	12.95	12.92	12.89	12.89	13.00

Thus, slight changes in feedgrain prices are more likely to be felt more in the prices of pork and poultry than for beef.

A final feature of the economic assessment results concern the regional effects. Regions display different ambient ozone levels and hence the changes in ozone under each analysis would lead to different yield responses for each region. Table 16 contains a breakdown of producers surplus values for each of the ten major regions in the assessment model for the base model and each ozone alternative. As is evident from the table, almost all regions benefit from reduced ozone and suffer losses from increased ozone. The greatest absolute benefits generally occur to those regions with greatest agricultural value of included crops; e.g., the Corn Belt and Lakes states. A few smaller regions, such as the Delta, also record large changes in surplus values.

In relative terms, the distribution of gains is somewhat different. As the "percent change" columns suggest, the regions that tend to gain the most from reduced ozone are those areas with fairly high ambient levels and a crop mix dominated by sensitive crops; i.e., soybeans and cotton. Regions that display some or all of these characteristics are the Pacific (including California), Delta, Northeast, and Southeast. Similarly, increases in ozone also hit these same regions the hardest. Other regions, like the Northern plains, receive almost no benefits (or losses) from adjustments in ozone in either direction due to relatively low ambient ozone levels.

Overall, the results of Analysis I indicate that the benefits of moderate ozone reductions are substantial in absolute terms but a relatively small percentage of total agricultural value (approximately 3 percent of gross crop value). The benefits of ozone reductions accrue to both producers and consumers, with about 60 percent of the consumer benefits accruing to foreign consumers. Domestic consumers benefit from slightly lower prices of livestock products, due to increased supplies of feedgrains and oil seed. Regionally, the major beneficiaries are those areas with high relative levels of ozone and ozone-sensitive crops.

The remaining analyses (Analyses II through V) are discussed below. Only the direct welfare effects of each analysis will be presented. The values generated in Analyses II through IV can be viewed as sensitivity analyses of the importance of response function and ozone assumptions used in the economic assessment. Analysis V provides some indication of the need to account for environmental interactions in future assessments. All the analyses include the hay yield adjustments.

Analysis II

This analysis represents an attempt to introduce regionalization of cultivars into the mix used in the assessment. The issue of extrapolating from site-specific experiments to meso or macro scale assessments is an uneasy one. Analysis I, by using the full set of available homogeneous data for several crops, represents one approach to smoothing out the problems of

Table 16. Annual effect of ozone on regional producers' surplus, including hay

		Ozone Assumption							
		10% Reduction		25% Reduction		40% Reduction		25% Increase	
Region	Base	Surplus	% Change	Surplus	% Change	Surplus	% Change	Surplus	% Change
		$ billion							
Northeast	0.551	0.569	3.27	0.575	4.36	0.601	9.07	0.516	-6.35
Lakes	3.743	3.788	1.20	3.782	1.04	3.828	2.27	3.681	-1.66
Corn Belt	7.261	7.404	1.97	7.492	3.18	7.633	5.12	7.106	-2.13
North Plains	3.576	3.570	--	3.578	--	3.599	0.60	3.559	-0.50
Appalachia	2.298	2.331	1.44	2.364	2.87	2.402	4.53	2.224	-3.22
Southeast	1.377	1.409	2.32	1.440	4.58	1.475	7.12	1.274	-7.48
Delta	1.348	1.395	3.49	1.448	7.42	1.495	10.91	1.224	-9.20
South Plains	2.540	2.549	0.35	2.573	1.30	2.603	2.48	2.485	-2.17
Mountain	2.508	2.506	--	2.570	2.47	2.576	2.71	2.439	-2.75
Pacific	0.813	0.820	0.86	0.984	21.03	1.059	30.26	0.614	-24.48
TOTAL	26.015	26.337	1.23	26.807	3.04	27.271	4.83	25.122	-3.43

extrapolation. To the extent that "proportionate" responses are observed to be statistically homogeneous, then site-to-site variability may be minimized. The alternative approach is to pool only those data (cultivars) from given regions. Unfortunately, only with soybeans have sufficient experiments been conducted (15 experiments covering 8 cultivars) to perform an effective regionalization. However, as observed in Analysis I, soybeans are one of the "driving" crops in the economic assessment; their ozone sensitivity leads to pronounced changes in own price and quantity. Analysis II uses these regionalized pooled soybean cultivars, in combination with the other response functions used in Analysis I. Again, the four ozone adjustments from 1980 ambient levels are used to generate yield changes.

The economic effects of ozone as captured by Analysis II are presented in Table 17. As is evident from the table, the effects of regionalizing the soybean responses is small; in general, the change in surplus estimates from the "with hay" analysis in Analysis I (Table 13) are less than 2 percent. The other general observations in Table 17 parallel those of Table 13; benefits increase with less ambient ozone, with consumers capturing the greatest total share of benefits but producers benefiting in relative terms. This latter occurrence again derives primarily from the open nature of the model associated with exports and production of livestock commodities.

The implication of this analysis is that the improvements in estimates from regionalizing the response functions for soybeans, corn and wheat are rather trivial. This does not mean that more cultivar information is unimportant. Rather, the analysis tends to reinforce the use of aggregate pooled responses as an acceptable measure of response. This observation is also a function of the available data sets, in that for some crops, regionalization was not possible, simply because there are insufficient cultivars. Also, only homogeneous data sets are used here; thus, it is unlikely that the yield differences would be great. The more extreme case is presented in Analysis III, where heterogeneous cultivars are used to project yield adjustments.

Analysis III

Analyses I and II attempt to deal with site or cultivar variability by pooling across homogeneous data sets. For most crops with multiple cultivar experiments, the majority of the cultivars are found to be statistically homogeneous, leading to similar relative yield changes. However, within each crop, there are one or more nonhomogeneous cultivars that display more extreme behavior. As noted earlier, it is unlikely that these extreme cultivar responses represent the "true" relationship between ozone and yields. However, their use in the current assessment can serve to define potential bounds on the economic assessments generated in Analyses I and II. Thus, in Analysis III, the soybeans, corn, wheat and cotton cultivars showing the maximum yield response (sensitivity) to ozone are used, in combination with the barley, sorghum and surrogate hay response, to define the next set of yield adjustments. The ozone assumptions are as defined in Analyses I and II.

Table 17. Economic effects of ozone: Analysis II

Ozone Assumption	Economic Surplus			Changes in Economic Surplus		
	Producers' Surplus	Consumers' Surplus	Total Surplus	Producers' Surplus	Consumers' Surplus	Total Surplus
	$ billion					
Base	26.015	114.957	140.971			
10% Reduction	26.350	115.379	141.729	0.335	0.422	0.758
25% Reduction	26.844	116.090	142.934	0.829	1.133	1.963
40% Reduction	27.253	116.520	143.744	1.238	1.563	2.803
25% Increase	25.037	113.512	138.549	-0.978	-1.445	-2.422

The economic effects of ozone yields predicted by these extreme cultivars are reported in Table 18. As expected, the estimates are substantially greater than those produced in Analysis I. These estimates are approximately 50 percent higher over the range of ozone levels than those of Analysis I. Specifically, the 25 percent ozone reduction now translates into benefits of $2.9 billion, rather than $1.9 billion as in Analysis I. This benefit estimate amounts to nearly 5 percent of the farm value of the primary crops. The greater economic estimates arise from the much greater yield adjustments associated with the extreme cultivar response.

The distribution of the effects across producers and consumers is similar to those observed in previous analyses, that is, the consumers benefit most from ozone reductions in absolute terms, but producers have a larger relative gain. Compared with Analysis I, however, the gain to consumers is slightly larger across all ozone levels, due in part to the larger shift in supply.

The importance of the 50 percent difference between the results of Analysis III and those in Analysis I depends on the willingness to believe that these cultivars more accurately portray the true (commercial) response of all cultivars of each crop. The statistical and plant science evidence reported in Heck et al. (1984b) and Rawlings and Cure (1984) suggests that the pooled responses are more likely to capture the true response. The results of Analysis III do imply that the estimates in Analysis I may be slightly low, given that these more sensitive cultivars are not represented in that average response but are part of the commercial mix of cultivars that make up total production of each crop. The percent of actual cropped acreage made up of the extreme cultivars (e.g., Davis for soybeans) however, is a small percent of the acreage percentage captured in the pooled cultivars.

Analysis IV

Ambient ozone levels display substantial variation from year to year, even when measured as a seasonal average. Given that seasonal ambient ozone levels are used in combination with a hypothetical ozone level to calculate the yield reductions, the base year used in an assessment may influence the yield changes and hence the economic effects. The previous three analyses are keyed to the 1980 ambient levels. A rank ordering of 1980 ozone levels among the production regions used in the analysis indicates that these 1980 values span the range from highest to lowest within the five year period 1978-1982. As an alternative base level, the average of the seasonal average ambient ozone levels is used to define the new ozone base. (Given the temporal variability displayed across regions, it was not possible to pick any year in the five year period that was uniformly high or low across all regions.) The effects of changing the ozone base are moderated in this study by the way alternative ozone levels are calculated (percent changes, rather than absolute departures, from ambient). Thus, the effects of changing ozone base are not as severe as may occur under a different analysis. Nonetheless, Analysis IV can provide some suggestions as to the role of ozone data in the assessment. The response function mix is that used in Analysis I.

Table 18. Economic effects of ozone: Analysis III

	Economic Surplus			Changes in Economic Surplus		
Ozone Assumption	Producers' Surplus	Consumers' Surplus	Total Surplus	Producers' Surplus	Consumers' Surplus	Total Surplus
	------------------------ $ billion ------------------------					
Base	26.015	114.957	140.971			
10% Reduction	26.390	115.713	142.104	0.375	0.756	1.133
25% Reduction	26.972	116.920	143.892	0.958	1.963	2.921
40% Reduction	27.212	118.243	145.455	1.197	3.287	4.484
25% Increase	24.844	112.867	137.711	-1.171	-2.090	-3.261

The differences in ozone levels between 1980 and the five year average ranges from only two to 26 percent among the 55 regions defined in the economic model. It is unlikely then that there will be major changes in economic effects. As Table 19 indicates, the values are rather close to those of Analysis I. For example, the 25 percent ozone reduction produces a $1.67 billion benefit as opposed to 1.93 in the same ozone scenario in Analysis I, a difference of 14 percent. A comparison of the other estimates with Analysis I reveals an even closer correspondence.

The particular year chosen for the base ozone value in the analysis thus seems to have little effect on the economic estimates so long as the extreme years are avoided. This is partly due to the use of a seasonally averaged exposure measure, which may smooth out the extremes in ozone events temporally and spatially, and the fact that the ozone alternatives are measured in terms of constant percent ozone adjustments from the base, rather than as absolute departures. The use of different exposure measures, as reported in Heck et al. (1984a), would probably increase the sensitivity of the assessment to the base ozone levels as would the use of ambient ozone level forecasts based on meterological modeling. In the current analysis, however, the choice of any other year from the available ozone data does not appear to be a critical issue.

Analysis V

The last permutation of Analysis I undertaken in this assessment effort is potentially the most important. Ozone effects, like any environmental stress, do not occur in isolation. Other yield-moderating influences occur simultaneously with the presence of ozone; some naturally, such as weather phenomenon, and others man-made, such as cultural and management practices. The previous four analyses (and all other economic assessments) have assumed that the effect of ozone on the yield or production response of a crop is analogous to neutral technological change, shifting the position of the crop response (or production) function upward or downward. In reality, interactions between ozone and other factors may also change the shape of the response surface. As discussed earlier, a few interactive NCLAN studies have examined ozone effects in the presence of moisture stress. These preliminary experiments (two on cotton and two on soybeans) indicate that water stress may dampen the response of ozone (lessen the slope) and hence result in a lower yield adjustment than expected from a non-water stressed plant. As discussed earlier and in Appendix C, the fact that much commercial production occurs under non-irrigated conditions suggests that response experiments based on adequately watered data may overstate yield losses.

Analysis V represents a preliminary attempt to account for this potential antagonistic interaction between water stress and ozone by using regional drought estimates for 1980, July rainfall yield regressions and a crop model to arrive at adjustment factors for the fully watered response functions. Although simplistic, this analysis can serve to reinforce the need for more information on the broad range of interactive processes. The cultivar mixes and ozone assumptions are those used in Analysis I.

Table 19. Economic effects of ozone: Analysis IV

Ozone Assumption	Economic Surplus			Changes in Economic Surplus		
	Producers' Surplus	Consumers' Surplus	Total Surplus	Producers' Surplus	Consumers' Surplus	Total Surplus
	$ billion					
Base	26.015	114.957	140.971			
10% Reduction	26.451	115.404	141.855	0.437	0.447	0.884
25% Reduction	26.542	116.100	142.642	0.527	1.144	1.671
40% Reduction	27.056	116.634	143.690	1.042	1.677	2.719
25% Increase	25.282	113.466	138.748	-0.733	-1.491	-2.223

As reported earlier, the adjustment factors used to modify the full-watered response data range from about .65 to 1.00 (no drought). Thus, the yield changes for each ozone level will be lower than in Analysis I, and the expectation is that the economic estimates should then be lower. This is demonstrated in Table 20. As the estimates indicate, the use of moisture stress adjustments in the analysis do lower the economic estimates. For example, the 25 percent ozone reduction now results in benefits of approximately $1.56 billion which is 20 percent lower than the $1.94 billion in Analysis I. Similar divergences are found in the three other ozone levels.

These differences are notable in that the underlying effect is quite plausible; that water stressed plants are less susceptible to ozone damage and that virtually all plants experience some moisture stress when grown under commercial conditions. This implies that the inclusion of moisture stress is an important consideration in accurately assessing the broad-scale effects of ozone. Further, its inclusion has a perceptible effect on the economic estimates. If this ozone-water stress hypothesis is correct (whether or not these adjustments are correct), then it seems highly likely that any future analysis of moisture stress-ozone interactions will lead to a reduction in the economic estimates generated from ozone yield data.

This moisture stress adjustment analysis also points to the need to address other interactions. It is possible that other interactions may have an equally important but opposite effect on the estimates. For example, increasing ambient ozone levels may predispose plants to insect or disease damage. If so, then the yield adjustments generated under controlled experiments may be understated if the experimental controls prevent the inclusion of such plant-pathogen effects in the data analysis. A similar case could perhaps be made concerning other environmental stresses.

VII. LIMITATIONS OF THE ANALYSIS

The environmental assessment performed in this study is an attempt to model a highly complex bioeconomic system. Not only must the important dimensions of the agricultural economic system be adequately portrayed, but the biological and technical possibilities associated with environmental stress on that system need to be addressed. Thus, it is possible that conceptual and empirical errors have been committed in implementing the assessment, including the uncertainty embedded in some of the biological and meteorological relationships that lie at the heart of the ozone assessment. Each of these sources of uncertainty need to be recognized in any use of the economic estimates derived in this study.

Three general areas of the assessment can be identified as contributing to the uncertainty in the estimates: the response data, the ozone data, and the economic model. Each has been developed and applied using best available information and theoretically consistent procedures. However, the assumptions and abstractions inherent in each can be viewed as caveats on the assessment

Table 20. Economic effects of ozone: Analysis V

	Economic Surplus			Changes in Economic Surplus		
Ozone Assumption	Producers' Surplus	Consumers' Surplus	Total Surplus	Producers' Surplus	Consumers' Surplus	Total Surplus
	------------------------ $ billion ------------------------					
Base	26.015	114.957	140.971			
10% Reduction	26.359	115.210	141.569	0.344	0.253	0.598
25% Reduction	26.659	115.874	142.532	0.644	0.917	1.561
40% Reduction	26.909	116.314	143.223	0.894	1.357	2.252
25% Increase	25.460	113.664	139.124	-0.555	-1.293	-1.847

results. These limitations can serve to suggest logical areas for further research. These three areas are discussed in more detail below.

The NCLAN response information represent the most complete available data set on crop yield response to ozone. The use of standard protocols over time and space in the NCLAN experiments facilitate the use of these data in assessments of this type. While the data provide strong evidence of the negative effects of ozone on crop yields, the procedures used to generate the data are not perfect. Several limitations of the experimental design and procedures are apparent. First is the failure to account for a range of environmental interactions in the experiments, such as moisture stress. This issue is currently being addressed, but only preliminary data are available for this assessment. Second, the data are also generated at a relatively few sites, requiring extrapolation to broad regional scales. Third, while data are generated under field conditions, the plants are in controlled chambers, which introduce biases, although the available evidence suggests that chamber effects are slight. Fourth, the exposure dynamics to date are confined to a seven-hour (0900 - 1600) per day exposure over the growing season. Longer daily exposures (e.g., 12 hour) may result in higher yield losses if stomatal activity occurs outside the 0900 to 1600 time window. Plants grown under natural conditions would then be exposed for a longer period than the seven hours from 0900 to 1600. In future NCLAN experiments, alternative exposure regimes will be employed to test this hypothesis.

In addition to experimental design and protocol questions, the crop mix and cultivars tested to date are limited to major annual field crops and a relatively few cultivars for each crop. Given limited resources, NCLAN management has focused on major annual crops. Crops such as rice, sugar beets and perennials have not been addressed. Also, with the exception of corn, soybeans and wheat, only one or two cultivars of each crop have been tested. Other cultivars may respond differently (though the soybean data suggest a rather common response across cultivars). Thus, while the current assessment covers a large percentage of annual field crops, the area of perennials and specialty crops is ignored. This exclusion of perennials and other crops is also a source of negative bias in the economic estimates, given that some of these crops are known to be sensitive to ozone.

The ambient ozone data used in the assessment are also open to question. Those data, based on the Kriging extrapolation procedure, again represent the best data currently available. The Kriging procedures used to derive the regional rural level estimates have been described in Heck et al. (1983a). One of the primary problems in calculating these ozone values is that the underlying SAROAD data are generally measured at urban or suburban monitoring sites and hence may not reflect rural concentrations. Further, for many states, there are fewer than ten monitoring sites from which to extrapolate to the entire state. These available data can establish temporal and spatial trends but the accuracy of the ambient ozone data for each agricultural production area may be limited by the available SAROAD data. However, a comparison of the Kriged ozone levels with actual values for a few NCLAN sites did reveal close correspondence (within 5 percent). It should also be noted that SAROAD data are collected at a height of three meters, whereas the crop canopy in the NCLAN chambers is lower (about one meter). Evidence suggests that ambient ozone levels are lower at the crop canopy than at three meters, implying an upward bias in yield effects predicted by SAROAD data.

The absence of available ozone models to project rural regional levels for use in formulating alternative ozone levels tends to diminish the utility of most assessments. That is, it is difficult to link alternative secondary ozone standards to probable rural ozone concentrations. This requires the use of either tenuous assumptions concerning the distribution of ozone levels or the use of constant percentage adjustments in ambient ozone, as employed here. While the constant adjustments are not a source of uncertainty per se, these assumptions may not correspond to levels that would be realized under alternative standards.

Finally, the economic model, with its many parameters and assumptions is a possible source of error in the economic estimates. While the validation of the model demonstrated its ability to simulate agriculture accurately, the estimates may be affected by the structure of the model. For example, as with most models of this type, a conceptual limitation is the absence of cross price effects between commodities. If the magnitude of such effects is sufficiently strong, then the consumer welfare impact of direct price effects (as included in this analysis) may be misstated. The direction of the bias will depend on the mix of substitutes and complementary commodities in the analysis. Also, the influence of income as a demand shifter has been omitted. The model does not include some mitigative adjustments, such as changes in fertilizer use rates, that may accompany yield changes due to ozone. Further, input usage and costs could decrease in the long-run if producers adjust output levels to the increased input productivity associated with reduced ozone. Finally, measurement errors in the economic data, statistical errors in the parameter estimates and algorithmic errors in the model solution procedure may also introduce biases. To the extent that these conceptual and empirical limitations will be constant across all model analyses, the potential biases should be minimized as the economic estimates are measured as deviations from the base solution, not as the total value of the objective function. The sensitivity of the model can lend some evidence as to the importance of these error sources but extensive sensitivity analysis on all parameters would require hundreds of costly model solutions. Limited examination of specific parameters indicated a fairly stable objective function value. However, like some of the other sources of uncertainty, the effects of assessment model uncertainty on the economic estimates are not fully quantifiable. In spite of these possible uncertainties associated with the analysis, the estimates generated here are considered to be more accurate and complete than any previously available.

VIII. SUMMARY

This manuscript is a report of an assessment of the economic consequences of ozone pollution on U.S. agriculture. The economic analysis is limited to those ozone effects directly associated with the production and consumption of a set of agricultural commodities. Effects on non-agricultural commodities as well as compliance costs of achieving any changes in ambient ozone levels are not evaluated here, hence the estimates are not net economic effects. The assessment is based on a large scale spatial equilibrium model of the U.S. agricultural sector. The ozone analyses are driven by ozone-yield response functions derived from four years of NCLAN data. The assessment covers the major annual crops in the U.S. and traces these crop yield effects through the livestock sector to final consumption, both domestic and foreign. It is the most comprehensive economic assessment of air pollution effects on agriculture undertaken to date.

The study involves multiple ozone analyses. Both alternative ozone levels and alternative yield response relationships are used to generate five distinct analyses (Analyses I-V). Each of the five major analyses includes four hypothetical adjustments in rural ambient ozone levels in the 55 production areas in the model. Until addition information is obtained on the factors or issues addresed in Analyses II - V, Analysis I is viewed as the most defensible set of economic estimates. Thus, analyses II - V are intended to provide evidence of the stability of the economic estimates in Analysis I to the underlying biological data base and assumption. The magnitude of the differences in estimates across assumptions can suggest areas for further research.

The economic model was validated by comparison with actual performance of the agriculture sector in 1980. Following the establishment of a credible base model, the model was perturbed according to the yield adjustments predicted in each of the ozone analyses. The resultant economic estimates indicate that benefits of reduced ozone will accrue to both agricultural producers and consumers. Specifically, a 25 percent change in ozone below current ambient levels results in a benefit to society of from $1.6 to $1.9 billion, depending on the underlying response assumption. Conversely, a 25% increase in ozone produces a cost (negative benefit) to society of $1.9 to $2.3 billion. Ozone alterations of 10 percent and 40 percent show lower or greater benefits, as expected.

The analysis of the effects of yield assumptions on economic estimates suggests that the incomplete treatment of other stress interactions in the design of the NCLAN experiments introduces some biases in the economic estimates. For example, introduction of moisture stress along with ozone, reduced the economic estimates by about 20 percent when compared with the ozone-response data that are derived from adequately watered field plots. Conversely, the use of a daily seven-hour exposure period rather than longer periods in the NCLAN experiments is probably imparting a downward bias to the economic effects. Other potential sources of positive or negative biases have been noted.

The ongoing research within NCLAN on moisture stress and alternative exposure dynamics can serve to improve on this area of uncertainty. In addition to better response data, future agricultural assessments can benefit from more SAROAD monitoring data in rural areas and the use of meteorological models to relate hypothetical Federal secondary ozone standards to rural ambient ozone concentrations that may result from those standards.

As is the case in virtually any economic study there are a number of things which could be done to improve, extend, clarify, or test the sensitivity of results of this analysis. These areas for further research include:

1. The analytical model could be extended to incorporate uncertainty (both as it occurs naturally in agriculture and as it is influenced by ozone) and farmers' attitudes toward uncertainty.

2. A more detailed validation exercise could be done on the model studying its ability to predict changes in the agricultural sector as a result of exogenous changes such as those induced by air pollution.

3. A study could be done on the impact of the crop mix assumptions as they influence the assessment. This would involve questions regarding both the influence of crop mixes vis-a-vis conventional single crop models and the influence of historical versus representative farm generated results.

4. An analysis could be done on the consequences of the level of spatial aggregation used in the model. In particular, the influence of the extra detail contained in the Corn Belt representative farms (relative to the micro-detail in other parts of the country) could be investigated. This would provide guidance on the desirability of more detailed disaggregation in the rest of the country in future analyses.

5. Analyses could be conducted on the factor neutrality-nonneutrality of ozone-induced technical change. The sensitivity of the assessment to alternative assumptions could be investigated.

6. The importance of cross elasticities of demand on the economic estimates could be studied, both in terms of developing relative estimates and examining the effect of alternative assumptions on the assessment.

Better data and refined assessment methodologies can lead to improved benefits forecasts. These in turn can assist regulatory agencies in setting environmental policies. The results of this national assessment, in combination with other recent economic assessments of ozone damage clearly establish that there are economic benefits to be attained from changes in ozone below current ambient levels. However, no attempt was made to estimate the cost of reducing ozone concentrations to the three levels for which benefits were estimated. Thus, these agricultural benefits, in combination with benefits accruing to other receptor classes and compliance costs of reducing ozone, can be used to gauge the net economic efficiency of potential ozone controls.

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APPENDIX A

The Analytics of the Assessment Model

The purpose of this appendix is to provide a description of the economic model and procedures to be used in the national assessment. This model is a modified version of that used in the Corn Belt assessment described above. The analytics of the model, including the link between micro or producer behavior and aggregate measures of welfare, are discussed in some detail. This is to allow the reader to grasp the essential features and assumptions of the model and to document the procedures that will be used in applying the model to the assessment of the national consequences of ozone. This presentation and discussion is also motivated in part by questions raised at the 1984 NCLAN peer review.

Description of the Aggregate Sector Model

The aggregate model used in the national assessment is a mathematical programming model based on the Takayama and Judge activity analysis spatial equilibrium model, the CHAC model of Duloy and Norton as explained in Norton and Solis (1981) and the agricultural sector models of Heady and associates (as reported in Heady and Srivistava, 1975). The particular model used here was developed by Baumes (1978), improved in data specification by Burton (1982), documented in Chattin et al., (1983), updated in the EPA Corn Belt study (Adams and McCarl, 1983) and updated for this study. The basic model has been used in the past in other studies by USDA and the Office of Technology Assessment. It has currently been adopted for routine use by USDA (House, 1983). The revisions inherent in this current model are motivated by the methodological suggestions of McCarl (1982a).

A complete description of the model is beyond the scope of this document (the reader interested in such should refer to any of the following: Chattin et al., 1983; House, 1983; Baumes, 1978 or Burton, 1982). In addition related conceptual material is given in McCarl and Spreen (1980); Norton and Schiefer (1980); Takayama and Judge (1971); Norton and Solis (1981); McCarl (1982); and Heady and Srivistava (1975). Nevertheless, we will briefly cover five topics of discussion. These topics regard the conceptual model including all producers, aggregation to a representative set of producers with less microeconomically detailed models, the overall model structure, calculation of economic surplus and the incorporation of air pollution (ozone)-induced yield changes.

A Conceptual Model Involving All Producers

Conceptually, the model development starts with the farm (this development is adapted from the more detailed presentation of McCarl and Spreen, 1980): A multi-product farm is assumed to maximize its profits (income minus cost). Income arises from product price times quantity of output produced summed over all products. Cost arises from the use of purchased inputs times their prices summed over all inputs. Total farm input usage is linked to farm activity as is farm output. It is further assumed that the time dimension is long run; thus fixed factors do not exist and all inputs are priced. Under these conditions the farm's profit maximization problem may be written as:

$$\text{maximize} \quad -\sum_j d_j X_j + \sum_o P_o Y_o - \sum_i C_i Z_i$$

$$\text{subject to} \quad \sum_j a_{ij} X_j - Z_i \leq 0 \quad \text{for all } i$$

$$-\sum_j e_{oj} X_j + Y_o \leq 0 \quad \text{for all } o$$

$$\sum_j f_{mj} X_j \leq b_m \quad \text{for all } m$$

$$X_j, Y_o, Z_i \geq 0$$

where

j refers to types of farm processes

o refers to types of farm outputs

i refers to types of farm variables

m refers to types of farm fixed inputs

d_j is miscellaneous costs of employing one unit of activity X_j

a_{ij} is the use of variable input i by one unit of activity X_j

e_{oj} is the production of output o by one unit of activity X_j

f_{mj} is the use of the firm's mth fixed inputs

b_m is the endowment of the mth fixed inputs

X_j is the number of units of farm activity j undertaken

P_o is the per unit price of the oth output

Y_o is the number of units of the oth output sold

C_i is the per unit price of the ith variable input

Z_i is the number of units of the ith input bought.

Given that the objective is to maximize this function then the conditions for optimality may be found through the application of the Kuhn-Tucker theorem. Thus for this problem to have an optimum we know that

1) $$\frac{\partial L}{\partial X_j} = -d_j - \sum_i \lambda_i a_{ij} + \sum_o U_o e_{oj} + \sum_m \alpha_m f_{mj} \leq 0 \qquad \text{for all } j$$

2) $$\frac{\partial L}{\partial Y_o} = P_o - U_o \leq 0 \qquad \text{for all } 0$$

3) $$\frac{\partial L}{\partial Z_i} = -C_i + \lambda_i \leq 0 \qquad \text{for all } i$$

4) $$\sum_j X_j \frac{\partial L}{\partial X_j} = 0$$

5) $$\sum_o Y_o \frac{\partial L}{\partial Y_o} = 0$$

6) $$\sum_i Z_i \frac{\partial L}{\partial Z_i} = 0$$

7) $$X_j \geq 0 \qquad \text{for all } j$$

8) $$Y_o \geq 0 \qquad \text{for all } o$$

9) $$Z_i \geq 0 \qquad \text{for all } i$$

10) $$\lambda_i \geq 0 \qquad \text{for all } i$$

11) $U_o \geq 0$ for all o

12) $\alpha_m \geq 0$ for all m

13) $\sum_j a_{ij} X_j - Z_i \leq 0$ for all i

14) $-\sum_j e_{oj} X_j + Y_o \leq 0$ for all o

15) $\sum_j f_{mj} X_j \leq b_m$ for all m

16) $\sum_i (\sum_j a_{ij} X_j - Z_i) \lambda_i = 0$

17) $\sum_o (-\sum_j e_{oj} X_j + Y_o) U_o = 0$

18) $\sum_m (\sum_j f_{mj} X_j - b_m) \alpha_m = 0$

Where

L is the augmented Lagrangian

U_o is the marginal value of output to the farm

λ_i is the marginal value of inputs to the farm.

α is the marginal value of fixed resources to the farm.

Conditions 1, 2, and 3 above give us optimal rules for the production, sale of outputs and the use of inputs. If we assume that Y_o and Z_i are produced (i.e., >0) then, by conditions 5 and 6, conditions 2 and 3 would be strict equalities. This leads to a solution in which the optimum value of U_o and λ_i equal the price of output and price of input, respectively. Thus, for a profit maximizing farm, the marginal revenue from producing more of an output is price and the firm equates prices to its marginal value of output. Similarly, the marginal cost of inputs is equated to their price. Thus the conditions for production are given by substituting into 1 which becomes

$$-d_j - \sum_i C_i a_{ij} + \sum_o P_o e_{oj} + \sum_m \alpha_m f_{mj} \leq 0$$

or

$$\sum_o P_o e_{oj} + \sum_m \alpha_m f_{mj} \leq \sum_i C_i a_{ij} + d_j$$

which implies at optimality that the profit maximizing farm produces output (X_j) until the marginal revenue of producing that output (summed price times output quantity) is less than or equal to the marginal cost of production (summed input cost times usage plus miscellaneous cost).

Given these profit maximizing conditions for an individual farm, one can form conditions for the agricultural sector. Implicit in the above discussion is the assumption that the price of outputs and inputs are constant regardless of the level of activity by the farm. This is hardly true of the aggregate. Clearly as the quantity of a crop produced decreases then the price to consumers increases. Similarly the prices of inputs such as labor and land would be related to quantity used. Thus, it is reasonable to adopt demand and supply functions for products and inputs. Let the price of these items be a linear function of the volume produced:

$$P_o = f_o(\overline{Y}_o)$$

$$C_i = g_i(\overline{Z}_i)$$

where

$f_o(\overline{Y}_o)$ is the inverse demand function for the Oth output

$\overline{Y}_o$ is total production summed across all farms

$g_i(\overline{Z}_i)$ is the inverse supply function for the ith input

Z_i is total use of the ith input.

Here we assume that the price of an item is dependent on own quantity only and that all other factors can be collapsed into the curve a priori.

Given these functions we may now write a set of first order conditions which includes the aggregate, but maintains the individual farm profit maximizing conditions. These conditions would involve a) the addition of a subscript for farm (k) on all the parameters and variables above; b) the inclusion of equations to form the aggregates

$$\sum_k Y_{ok} - \overline{Y}_o = 0$$

$$\sum_k Z_{ik} - \overline{Z}_i = 0;$$

c) the inclusion of aggregate dual variables ($\overline{U}_o, \overline{\lambda}_i$) which equal the firm shadow prices (U_{ok}, λ_{ik}) for all firms; and d) the inclusion of a relationship between the aggregate price and the shadow price

$$f_o(\overline{Y}_o) - \overline{U}_o \leq 0$$

$$-\overline{\lambda}_i + g_i(Z_i) \leq 0;$$

These equations describe a situation under which all the firms maximize profits in a perfectly competitive agricultural sector. The conditions are duplicated by the following optimization model which is a generalization of equation (9):

$$\text{maximize} \quad \sum_o \int_0^{\overline{Y}_o} f_o(Y)dY + \sum_i \int_0^{\overline{Z}_i} g_i(Z)dZ$$

$$+ \sum_k \sum_{j(k)} d_{jk}X_{jk}$$

$$\text{subject to} \quad \sum_{j(k)} a_{ijk}X_{jk} - Z_{ik} \leq 0 \text{ for all k and i}$$

$$\sum_{j(k)} a_{ojk}X_{jk} + Y_{ok} \leq 0 \text{ for all k and o}$$

$$\sum_k Z_{ik} - \overline{Z}_i \leq 0 \text{ for all i}$$

$$\sum_k Y_{ok} - \overline{Y}_o \qquad \leq 0 \text{ for all } o$$

$$X_{jk}, \overline{Y}_o, \overline{Z}_i, Y_{ok}, Z_{ik} \geq 0$$

This forms the base conceptual framework underlying this assessment (see McCarl and Spreen for a more detailed development).

Aggregation

The above model explicitly works with individual farms. Such microeconomic detail for every farm is unrealistic in an empirical study of the scope undertaken here. Consequently, following the procedures of all previous spatial equilibrium studies we use geographically "homogeneous" producers. The assumption is adopted therefore that within each geographical region the model for the region is adequately representative of all producers in the region. Hueristically, this would occur, following the exact aggregation literature, if all producers had the same possibilities and resources, and all technical coefficients were proportional across farms (see Day, 1963, Miller, 1964, Paris and Rausser, 1983, and Spreen and Takayama, 1980, for elaboration). Sheehy and McAlexander, 1965, and Frick and Andrews, 1965, discuss procedures for minimizing bias.

However, we have yet a further aggregation difficulty concerning microeconomic detail. At a minimum there are 55 representative farm models within the national model. The Corn Belt models each could have as many as 220 constraints and 400 activities (following Brown and Pheasant, 1983). Extrapolating to all regions the farm production component could have more than 12,000 constraints and 22,000 activities. This is unrealistic given data and computer cost limitations. Consequently the decision was made to construct more aggregate microeconomic representations. This was done following the suggestions of McCarl in which crop mixes were used to specify activities. The crop mixes were generated using the representative farm models of Brown and Pheasant (1983) for the Corn Belt and historical information in combination with USDA Farm Enterprise Data System (FEDS) data for the regions outside the Corn Belt.

Model Structure

The above material has presented a view of the model which does not fully document its empirical characterization of the agricultural sector. Here we will present a summation notation representation of the model. This representation is not exhaustive as the actual empirical model has in excess of 1,400 columns and 200 rows with numerous bounds.

The model contains the following symbols and associated definitions:

Definition of Variables

X_{tr} - the t^{th} agricultural production activity in region r.

XP_t - t^{th} processing activity.

NI_p - quantity of national input p supplied.

Ψ_ℓ - domestic consumption of the ℓ^{th} primary agricultural commodity.

$\eta_{n\ell}$ - n^{th} step on the excess supply function facing the U.S. for the ℓ^{th} agricultural commodity.

Γ_c - domestic consumption of the c^{th} processed commodity.

Υ_{nc} - n^{th} step on the excess demand curve for the c^{th} processed commodity facing the U.S.

θ_{rq} - supply of the q^{th} land type in region r.

λ_r - supply of hired labor for the r^{th} region.

$FAMLB_r$ - use of farm family labor in the r^{th} region.

Technical Coefficient Definitions

$a_{tr\ell}$ - per unit yield of the ℓ^{th} agricultural commodity in the t^{th} production activity in the r^{th} region.

$a2a_{trc}$ - per unit usage of the c^{th} processed commodity in the t^{th} production activity in the r^{th} region.

$h_{t\ell}$ - per unit use of the ℓ^{th} agricultural commodity in the t^{th} processing activity.

$\Pi_{n\ell}$ - the quantity of the ℓ^{th} agricultural commodity imported at the n^{th} step of the excess supply curve facing the U.S.

$a2_{tc}$ - per unit yield of the c^{th} processed commodity from the t^{th} processing activity.

$II2_{nc}$ - quantity of the c^{th} processed commodity imported at the n^{th} step on the excess supply curve facing the U.S.

$kk_{n\ell}$ - quantity of the ℓ^{th} agricultural commodity exported at the n^{th} step on the excess demand curve facing the U.S.

ww_{nc} - quantity of the c^{th} processed commodity exported at the n^{th} step of the excess demand curve facing the U.S.

lb_{tr} - per unit use of agricultural labor in the t^{th} agricultural production activity for the r^{th} region.

ln_{trq} - quantity of the q^{th} land type used per unit of the t^{th} production activity in the r^{th} region.

lnS_{tsqr} - quantity of the q^{th} land type used in the S^{th} state by X_{tr}.

I_{trp} - per unit use of the p^{th} national input in the t^{th} agricultural production activity in region r.

$NI2_{tp}$ - per unit use of the p^{th} national input in the t^{th} processing production activity.

d_{trj} - per unit use of the j^{th} agricultural production regulation by the t^{th} production activity in the r^{th} region.

$d2_{tw}$ - per unit use of the w^{th} processing regulation by the t^{th} processing activity.

$d3_{ps}$ - per unit use of the s^{th} input regulation by the p^{th} national input.

$d4_{qrs}$ - per unit use of the s^{th} input regulation by the q^{th} land type in the r^{th} region.

$d5_{rs}$ - per unit use of the s^{th} input regulation by agricultural labor in the r^{th} region.

Objective Function Cost Coefficients

b_{tr} - per unit cost of the t^{th} agricultural production activity in the r^{th} region.

$q_r(\lambda_r)$ - area generating function for labor supply curve for the r^{th} region at quantity λ_r.

$h_{rq}(\theta_{rq})$ - area generating function for land supply of the q^{th} type in the r^{th} region.

Z_p - cost of supplying one unit of the p^{th} national input.

g_t - per unit cost of the t^{th} processing production activity.

$dd_{n\ell}$ - area under the excess supply curve facing the U.S. for the ℓ^{th} agricultural commodity up to the n^{th} step.

xx_{nc} - area under the excess supply curve facing the U.S. for the c^{th} processed commodity up to the n^{th} step.

bb_{ℓ} - area generating function for the domestic demand curve for the ℓ^{th} agricultural commodity.

rw_r - reservation wage for farm family labor in the r^{th} region.

$gg_c(\Gamma_c)$ - area generating function under the domestic demand curve facing the U.S. for the c^{th} processed commodity.

$mm_{n\ell}$ - area under the excess demand curve fcing the U.S. for the ℓ^{th} agricultural commodity up to the n^{th} step.

yy_{nc} - area under the excess demand curve facing the U.S. for the c^{th} processed commodity up to the n^{th} step.

Right Hand Side Definitions

ccc_r - quantity of farm family labor in the r^{th} region.

ddd_{qr} - initial land endowment of the q^{th} type in the r^{th} region.

eee_s - maximum land use in state s.

fff_p - initial stock of national input p.

The formal linear programming model is given below.

Agricultural Commodity - Marketing Clearing

$$(1)\quad -\sum_{t=1}^{T_1}\sum_{r=1}^{R} a_{tr\ell}\, X_{tr} + \sum_{t=1}^{T_2} h_{t\ell}\, XP_t - \sum_{n=1}^{N} \Pi_{n\ell}\, \alpha_{n\ell}$$

$$+ \sum_{n=1} kk_{n\ell}\eta_{n\ell} \le 0$$

$\ell = 1, 2, \ldots L$

Equation (1) states that production of the t^{th} agricultural commodities by all technologies employed in all regions less the total quantity demanded as inputs by the processing sector, plus imports of the commodity, less domestic consumption, less foreign demand or exports, must be greater than or equal to zero. Or, more simply stated, quantity supplied is greater than or equal to quantity demanded.

Secondary Commodity - Market Clearing

$$(2)\quad -\sum_{t=1}^{T_2} a2_{tc} XP_t - \sum_{n=1}^{N} \Pi2_{nc}\, T_{nc} + \Gamma_c + \sum_{n=1}^{N} ww_{nc}\, \Upsilon_{nc}$$

$$+ \sum_{t=1}^{T_1}\sum_{r=1}^{R} a2a_{trc} X_{tr} \le 0$$

$c = 1, 2, \ldots, C$

Equation (2) is the same relationship as equation (1), except it refers to processed commodities. Production plus imports, less domestic demand, less exports, is greater than or equal to zero.

Regional Agricultural Labor - Market Clearing

$$(3)\quad FAMLB_r + \sum_{t=1}^{T_1} lb_{tr} X_{tr} - \lambda_r - ccc_r \le 0$$

This equation represents the supply and demand interaction in the agricultural labor market by region. The amount of labor demanded by all technologies must be less than or equal to the hired labor supplied plus the family labor used, where family labor used must not exceed the stock of family labor.

Agricultural Land - Marketing Clearing

$$(4) \quad \sum_{t=1}^{T_1} \mathrm{ln}_{trq} X_{tr} - \theta_{rq} - ddd_{qr} \leq 0$$

$q = 1, 2, \ldots, Q \quad r = 1, 2, \ldots, R$

The land required by each technology or production activity employed cannot exceed the land supplied in the region.

$$(5) \quad \sum_{t=1}^{T_1} \ell nS_{tsqr} X_{tr} \quad -eee_{sq} \leq 0$$

$s = 1, 2, \ldots, NS$

The land required in a state cannot exceed the maximum tillable acres.

National Inputs - Market Clearing

$$(6) \quad \sum_{t=1}^{T_1} \sum_{r=1}^{R} I_{trp} X_{tr} + \sum_{t=1}^{T_2} NI2_{tp} XP_t - NI_p - fff_p \leq 0$$

Equation (6) introduces the interrelationship between the processing and agricultural sector. The use of national inputs in all of agriculture plus the use of national inputs in processing must be less than the quantity purchased plus the quantity already owned.

Foreign Demand - Agricultural Commodities

$$(7) \quad \sum_{n=1}^{N} \eta_{n\ell} \leq 1 \qquad \ell = 1, 2, \ldots, L$$

Foreign Demand - Processed Commodities

$$(8)\quad \sum_{n=1}^{N} \gamma_{nc} \leq 1 \qquad\qquad c = 1, 2, \ldots, C$$

Equations (7) and (8) are constraints to insure that a convex combination of adjacent linear segments on the specified price responsive supply (factors) and demand (outputs) curves are chosen in solution following Duloy and Norton (1973).

Objective Function

maximize

$$(9)\ -\sum_{t=1}^{T_1} \sum_{r=1}^{R} b_{tr} X_{tr} - \sum_{r=1}^{R} q_r(\lambda_r) - \sum_{r=1}^{R} \sum_{q=1}^{Q} h_{rq}(\theta_{rq})$$

$$-\sum_{p=1}^{P} Z_p NI_p - \sum_{t=1}^{T_2} g_t XP_t + \sum_{\ell=1}^{L} bb(\Psi_\ell)$$

$$-\sum_{c=1}^{C} gg_c(\Gamma_c) + \sum_{\ell=1}^{L} \sum_{n=1}^{N} mm_n \quad \eta_{n\ell}$$

$$+\sum_{c=1}^{C} \sum_{n=1}^{N} yy_{nc}\gamma_{nc} + \sum_{\ell=1}^{L} \sum_{n=1}^{N} rw_r FAMLB_r$$

Equation (9) is the total sum of producers' plus consumers' surpluses realized for all markets; factor market and output or product market.

When given the appropriate technical coefficients, objective function cost coefficients and right hand side values, the maximization of equation (14) subject to constraints (1) - (8) leads to a competitive equilibrium. Equilibrium price and quantity levels for factors of production, agricultural and nonagricultural commodities are determined endogenously subject to the constraints imposed on the model.

The area generating functions are formed as followed. The curves are basically either infinitely or finitely elastic. The infinite elasticity cases for some inputs reflect a constant price (times quantity). The finite elasticity curves for outputs are put in as a kinked curve, which is infinitely elastic to a point, then display a constant elasticity (to avoid unrealistic solutions and enhance analytical tractability). The join point occurs at a different point for supply and demand curves. The floor price for supply curves is the price which is the larger of one-third the 1980 equilibrium price or the price which would generate one-third the 1980 equilibrium quantity on the constant elasticity curve which would pass through the 1980 equilibrium price and quantity. The ceiling price for the demand curve is the smaller of three times the 1980 price or that price which would generate one-third the 1980 quantity. Thus, the area under these curves is calculated as in the attached figures (Figures 1a, 1b and 1c). The term PMIN is the floor or ceiling price. The area to that point is PMIN times quantity; the additional area from the intersection of PMIN and the constant elasticity curve is calculated by integration.

The reader should note that the product supply functions implicit within this model are not constant elasticity but rather are curves which are projected through the production process.

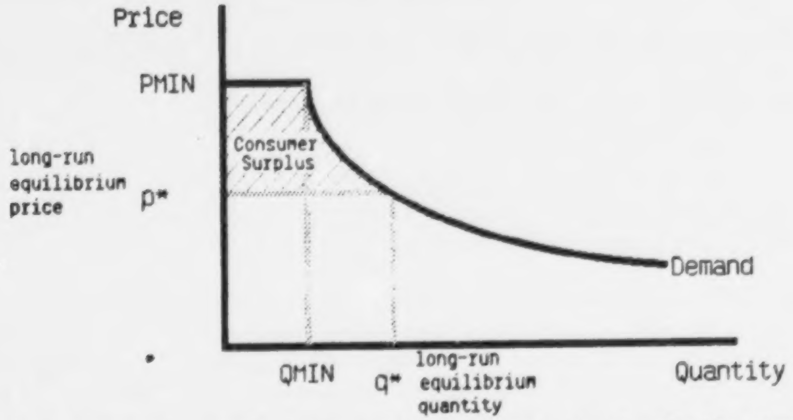
As with any attempt to model a complex system, the mathematical model above has its limitations. The first of these is the assumed independency of the factor supply and product demand schedules. The cross price effects for supply (of inputs) and demand (for outputs) is omitted. Secondly, the influence of income generated as a demand shifter has been omitted. Thus, demand curves supplied to the model may over or under estimate the true demand if income is different than the base year.

Welfare Measures: Economic Surplus

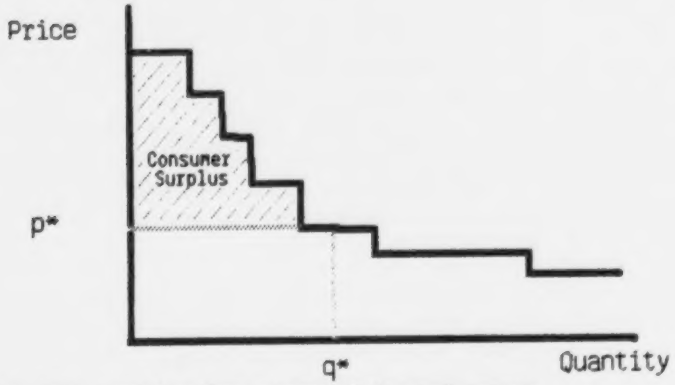
The objective function of the sector model is used to obtain measures of social benefits from changes in air quality. The sector model features demand relationships for sectoral outputs (commodities) of various types. The elasticity, and equation forms vary with end use; export demand is elastic. Assuming supply and demand functions which are integrable and independent of sector activity, first order conditions are then met in the sector model specification. The objective function of this specification is empirically specified in equation (9) but can be conceptually represented as

$$\text{maximize} \qquad \Pi = \sum_i g_i(Z_i) - \sum_j e_j(X_j) - \sum_m c_m Y_m$$

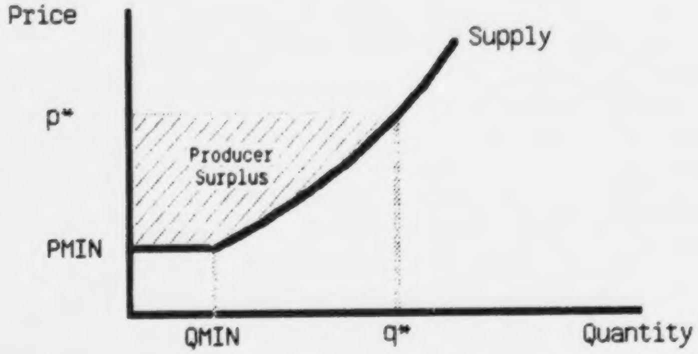
where Π is the sum of ordinary consumers' surplus and producers' surplus and the integrals are evaluated from zero to Z_i^*, the amount of i^{th} commodity produced and sold to consumers; and from zero to X_j^*, the amount of the j^{th} factor used. The parameters are as follows:


Price
PMIN
long-run
equilibrium
price
p*
Consumer
Surplus
Demand
QMIN
q*
long-run
equilibrium
quantity
Quantity

(1a) Consumer surplus for modified constant elasticity demand curve


Price
Consumer
Surplus
p*
q*
Quantity

(1b) Consumer surlpus for stepped demand curve


Price
Supply
p*
Producer
Surplus
PMIN
QMIN
q*
Quantity

(1c) Producer surplus for modified constant elasticity supply curve

Figure A.1 Calculation of economic surplus

$g_i(Z_i)$ is the area under the demand function for the i^{th} product;

$e_j(X_j)$ is the area under the supply function for the j^{th} factor;

$c_m(Y_m)$ is the miscellaneous cost of production;

subject to the technical and behavioral constraints defined above. Given the micro and macro structure of a model, the sector model solution then simulates a long-run, perfectly competitive equilibrium.

Following Samuelson (1952), the objective function (Π) may be interpreted as a measure of ordinary consumers' and producers' surplus (quasi-rents) or net social benefit. Analytically, this is defined as the area between the demand and supply curves to the left of their intersection. The demand functions are specified at the national level, as are aggregate production responses. The producer quasi-rents are measured through the factor markets (land and labor). The use of these measures has been demonstrated in Just et al. (1981) and Just and Hueth (1980) to be analogous to measurement of producers surplus through the aggregate supply function. Justification for the use of economic surplus in policy analysis is well documented in the literature (Willig, 1976; Just et al., 1981) and is particularly relevant to agricultural uses where distributional consequences are of concern. By imposing alternative ozone levels on the producer behavior, as manifested in yields predicted by the NCLAN response functions, changes in production and consumption and ultimately economic surplus may be measured. Comparisons of changes in surplus between the alternative ozone levels and current ambient concentration indicates the benefits for these alternative ozone levels.

The mechanics for calculating producer and consumer surplus is a straight forward application of integration and optimization procedures. The mathematical program used to solve the sector model calculates the value of the nonlinear objective function. This objective function is calculated by integrating the area under the demand curves less the area under the supply curves less other costs.

In the model, demand curves are of three main types: constant elasticity, perfectly elastic, and step-like curves. The consumer surplus is calculated as the area between the demand curve and price line. However, the area below a constant elasticity demand curve and above the price line does not sum to a limit. Consequently, the constant elasticity demand curves have been truncated at a level equal to one-third the initial equilibrium price, or one-third the initial equilibrium quantity, whichever is associated with the smaller quantity. The truncated demand curve is then joined to a perfectly elastic demand curve at that level (see Figure A1).

Supply curves for land and labor are also of the constant elasticity type. A similar truncation occurs for these curves since it is unrealistic to expect these curves to pass through the origin. The producer surplus is calculated by commodity. However, producer and consumer surplus can also accrue when a production or consumption constraint is active. In this case, there will be an addition to the surplus as measured by the area below the price line and above the supply curve if an upper limit on production is reached, or a subtraction from that area if a lower limit is active. This area is calculated by multiplying the constraint shadow price times its right-hand side. No constraints on consumption were imposed in the model.

Thus, only two deviations from the standard calculation of consumer and producer surplus occurred. The first related to the modification of constant elasticity supply and demand curves. The second deviation incorporated the welfare effect of constraints on production.

Incorporation of Ozone Effects

The ozone induced yield effects were included in the model through a modification of the a_{tr} term in the agricultural commodity-market clearing row. This modification involved the multiplication of the coeficient by a yield adjustment parameter which was state and crop specific. These yield adjustment parameters are derived from the NCLAN data and resultant response functions reported in Table 7. The respective yield adjustments for each crop, region and ozone alternative are presented in Appendix D. This type of adjustment requires the assumption that ozone induces a neutral technological change; i.e., that other resources (labor, fertilizer) will not adjust independently in response to an adjustment in ozone. Thus, the same fixed input proportions are assumed before and after ozone. Other assumptions could have been used, but there was little empirical basis for changing the resource mix.

Appendix B

Estimation of the Yield-Acreage Response for Use in Generating Crop Alternatives

Agronomic and economic factors suggest that own crop acreage can affect yield in several ways.

(i) It is assumed that crops are grown on land that has a comparative advantage for the production of that crop. If the acreage planted to a certain crop is a dominant land use, increases in acreage can only be onto land less suited for the production of that crop. This implies that average yields will decline. The effect in a given region will depend on total land availability and the magnitude of the increase in acreage. For crops of minor importance in a region, the effect of acreage increases on yield is uncertain. However, if the effect is a positive one, one would expect that as more land is planted to that crop, the yield increase will occur at a diminishing rate after a point.

(ii) Farms are often equipped to handle a maximum acreage of a crop. Once this crop acreage is exceeded, factors relating to the timeliness of production have an effect. Even if no other crops were grown, timeliness may be a problem, for example, if all the crop cannot be harvested at the "optimal time". Thus, expansion past this maximum level will lead to negative yield effects if the expansion is not associated with a corresponding increase in inputs.

(iii) Continuous planting of a given crop can have an important effect on yield if a build-up in disease or parasite population is likely to occur. This will reduce yields.

Acreage of other crops can affect yield of a particular crop in two main ways:

(i) Yield can be affected by the crop that was planted on that land the previous year. Alterations in crop patterns can be beneficial to yield, if the previous crop was a legume or if the land had been fallow. Conversely, the previous use pattern can be detrimental to yield if that crop had a large nutrient demand or deteriorated the soil structure.

(ii) Other crops planted in the same year affect yield by competing for resources such as labor, machinery, or management time.

Since expected crop price is a primary factor in determining acreage (planting decisions), and acreage can affect yield, it is important to accurately model the crop yield-acreage relationship. If the response relationship between yields and acreage is ignored, the acreage response arising from changes in expected price would likely be overstated. This would then bias a subsequent ozone analysis where changes in relative crop yields are used to portray the effects of alternative ozone levels.

The General Approach

The steps involved in adjusting expected yield to account for acreage changes were:

1. Collection of aggregate state production and acreage data on the 10 principal crops in the U.S.;

2. aggregation of state data to conform to the regional definitions.

3. a system of equations expressing yield as a function of crop acreage and other variables were specified and estimated for each region;

4. the system of equations was used to provide a yield prediction for each of the historical crop average mixes used in the sector model holding all variables except acreage at the 1980 levels.

5. the predicted yield for each year was divided by the 1980 predicted yield to form a yield modifying ratio.

In the linear program (farm level component) of the economic model, activities were not represented as production units of individual crops, but as the combination of crop production arising from the relative acreage of each crop planted in a particular year. The 1980 yields for each crop mix in each region were adjusted to account for the acreage mix using the yield modifying ratio prior to inserting the activity into the LP matrix. Thus, each crop mix will have been corrected for the acreage effect of the crop mix on yield, and will be at a realistic level because the crop mix included in the LP solution was an historical observation.

Crop yields were modeled for: corn for grain, corn for silage, soybeans, wheat, oats, barley, sorghum for grain, hay, cotton and rice, in regions where these crops were grown. The data were for years 1960-1981 and were taken from "Agricultural Statistics." The systems of equations were estimated using Zellner's seemingly unrelated regression method (Zellner, 1962) because the disturbances between equations within the system were expected to be correlated.

Once the model was estimated econometrically, the yields were predicted for the years 1970-1981 holding the dummy intercept and time variables at the 1980 level. The subsequent predictions were then divided by the 1980 prediction to obtain the yield modifying ratios.

Model Results

Assessing the quality of the results for such a model was made more difficult because the correct sign of some variables could not be determined *a priori*. The other acreage effect ($AC_{j,t}$), for example, could be either positive or negative depending on the crop; being more or less competitive for resources than at the average level. Interpretation of coefficients was complicated because of the multicollinearity introduced by expressing acreage variables as a percentage of the regional crop acreage in that year. Thus, one acreage variable could not increase without another decreasing. However, the structure of the model was not considered as important as the ability to predict acreage response effects.

For the model to be successful, the explanatory variables needed to be uncorrelated with weather. The more the explanatory variables were correlated with weather, the more the weather effect, rather than the yield effect, was being modeled.

A priori knowledge provided two possible checks. First, because acreage effects were thought to have relatively small effects on yield, the yield acreage effects were expected to show a small variance. Second, if only the acreage effect had been modeled, it would be unreasonable for the yield modifying ratios in a particular year to be all above, or all below the 1980 base value of one, since such a result is more likely to be to the consequence of weather, not acreage changes.

The model, as estimated, appeared successful. The variation in the yield ratios were generally small, and it was not obvious that excluded weather effects had been captured by the explanatory variables. Trends on acreages reflected increases in the yield of one crop countered by decreases in the yields of other crops.

For the most part, signs of the major crops between regions were consistent. In addition, with the exception of cotton, the major crops that showed a positive own acreage effect had a negative effect of the margin. The net effect of any biases in the estimates is dampened by the procedure used to incorporate them in the analysis. The adjustments, measured as a ratio relative to base yields are quite small, and distributed about the 1.0 value. A value greater than one for a given crop tends to be offset by values of less than one for other crops. Both the effect of changes in acreage on yield and the countervailing effects in own and competing crop prices tend to constrain the model to historically consistent crop mixes.

APPENDIX C

Use of a Crop Model to Generate Moisture Stress Adjustment Factors

The quantitative factors used to adjust the well-watered ozone response functions are derived from a general crop model that includes ozone and water effects on crop yields. This model is described by King and Snow (1984). To simulate the drought-ozone interaction in this model, marketable yield Y is expressed as the product of seasonal transpiration (ST) and transpiration efficiency (TE), i.e.,

$$Y = ST \cdot TE$$

This assumes that drought acting alone affects ST but not TE. Thus, drought reduces yield in proportion to its effect on ST. Seasonal transpiration (ST) is calculated with a simple soil water balance submodel, similar to that described by Hanks and Hill (1980). The transpiration model reduced transpiration on days when the plant available soil moisture falls below a threshold value.

The model assumes that ozone reduces both ST and TE, but that less ozone damage occurs on days of drought stress than would occur for well-watered crops. Also, ozone is assumed to reduce the rate of root zone development. Both of the above ozone effects influence soil moisture status. Thus, the model accounts for ozone effects on water use plus drought effects on ozone damage.

The model is used to generate a curve (Figure 4) depicting probable adjustment factors to the well-watered ozone response functions. This was done by running the model with and without ozone over a range of drought severities. The model was run using Indianapolis, Indiana hourly ozone values for 1978, and with a representative 1978 rainfall record from an Indiana weather station. Daily potential evapotranspiration was derived from Indiana weather records. To estimate a drought stress factor, the model was adjusted to produce a 10 percent ozone loss for the well-watered case. The model was then run with the above rainfall input, with and without ozone. In this case, ozone produced a 6.9 percent yield loss and drought produced a 16.5 percent loss in the presence of ambient ozone. Thus, the model predicts that a drought which reduces yield by 16.5 percent (from the well-watered case) modifies the well-watered ozone effects (expressed as a percent) by a factor of 0.69. (For this prediction to be generally true, all combinations of rainfall and evapotranspiration producing a given drought effect must also have the same effect on ozone-caused losses. Simulations to date indicate that the timing of rainfall ozone episodes also influences the drought-ozone interaction.)

To estimate the correction factor for other than the 16.5 percent drought associated with the above rainfall record, the rainfall record was multiplied by a constant which varied from .6 to 1.6. The model was then run with the proportionally adjusted rainfall records to produce a plot of the correction factor as a function of drought severity. This plot was approximated with the three line segments of Figure 4. The middle line segment of that curve is a least squares fit to the 6 points in the 9 to 33 percent drought interval. The drought effect on ozone-caused loss was quite nonlinear for drought effects of 0 to 8 percent. Because drought is patchily distributed across a region (varying with microtopography) this nonlinearity will bias the correction factor if it is calculated from average drought effects for a region. To correct for this bias (in a crude fashion) it is assumed that the correction factor was linear from 0 to 10 percent drought as shown in Figure 4. (This assumption would be strictly correct if regions with average drought reduction of 0 to 10 percent were composed only of fields with no drought stress and fields with a 10 percent yield reduction due to drought.) For drought effects greater than 33 percent, there appeared to be little change in the ozone response to drought.

It should be noted that the figure was produced assuming a crop cover development and season length comparable to that of soybeans. It is believed that crops with different season lengths may show a rather similar drought-ozone interaction when the interaction is expressed in terms of percent yield reduction due to drought. However, this has not been verified. The modeled correction factor may also vary somewhat for ozone scenarios other than the zero vs. 10 percent well-watered ozone effect used to construct Figure 4.

APPENDIX D

Supporting Response and Ozone Data

Table D.1. Actual and adjusted seasonal average ozone levels by state, 1978-1982 a/

Year State	1978	1979	1980	1981	1982	1978-1982 Average
	(parts per billion)					
Alabama	50.47	41.22	46.98	47.28	50.43	47.3
10% reduction	45.40	37.10	42.30	42.60	45.40	
25% reduction	37.90	30.90	35.20	35.50	37.80	
40% reduction	30.30	24.70	28.20	28.40	30.30	
25% increase	63.10	51.50	58.70	59.10	63.00	
Arizona	45.62	42.48	51.63	47.93	46.07	46.7
10% reduction	41.10	38.20	46.50	43.10	41.50	
25% reduction	34.20	31.90	38.70	35.90	34.60	
40% reduction	27.40	25.50	31.00	28.80	27.60	
25% increase	57.00	53.10	64.50	59.90	57.60	
Arkansas	56.62	50.14	51.47	47.62	45.56	50.3
10% reduction	51.00	45.10	46.30	42.90	41.00	
25% reduction	42.50	37.60	38.60	35.70	34.20	
40% reduction	34.00	30.10	30.90	28.60	27.30	
25% increase	70.80	62.70	64.30	59.60	57.00	
California	46.82	51.14	52.04	50.44	46.29	49.3
10% reduction	42.10	46.00	46.80	45.40	41.70	
25% reduction	35.10	38.40	39.00	37.80	34.70	
40% reduction	28.10	30.70	31.20	30.30	27.80	
25% increase	58.50	63.90	65.10	63.10	57.90	
Colorado	50.36	51.32	50.92	48.10	50.42	50.2
10% reduction	45.30	46.20	45.80	43.30	45.40	
25% reduction	37.80	38.50	38.20	36.10	37.80	
40% reduction	30.20	30.80	30.60	28.90	30.30	
25% increase	63.00	64.20	63.70	60.10	63.00	
Connecticut	45.50	49.50	58.83	51.00	51.33	51.2
10% reduction	41.00	44.60	52.90	45.90	46.20	
25% reduction	34.10	37.10	44.10	38.30	38.50	
40% reduction	27.30	29.70	35.30	30.60	30.80	
25% increase	56.90	61.90	73.50	63.80	64.20	
Delaware	43.00	45.00	36.00	54.00	49.00	45.4
10% reduction	38.70	40.50	32.40	48.60	44.10	
25% reduction	32.30	33.80	27.00	40.50	36.80	
40% reduction	25.80	27.00	21.60*	32.40	29.40	
25% increase	53.80	56.30	45.00	67.50	61.30	

Table D.1. (continued)

Year State	1978	1979	1980	1981	1982	1978-1982 Average
	(parts per billion)					
Florida	42.98	34.69	35.33	42.51	38.87	38.9
10% reduction	38.20	31.20	31.80	38.30	35.00	
25% reduction	31.90	26.00	26.50	31.90	29.20	
40% reduction	25.50	20.80*	21.20*	25.50	23.30*	
25% increase	53.10	43.40	44.20	53.10	48.60	
Georgia	54.65	43.40	46.82	45.87	45.65	47.3
10% reduction	49.20	39.10	42.10	41.30	41.10	
25% reduction	41.00	32.60	35.10	34.40	34.20	
40% reduction	32.80	26.00	28.10	27.50	27.40	
25% increase	68.30	54.30	58.50	57.50	57.10	
Idaho	N.A.	51.00	45.71	47.60	47.88	38.4
10% reduction	N.A.	45.90	41.10	42.80	43.10	
25% reduction	N.A.	38.30	34.30	35.70	35.90	
40% reduction	N.A.	30.60	27.40	28.60	28.70	
25% increase	N.A.	63.80	57.10	59.50	59.90	
Illinois	49.92	45.30	46.92	41.69	45.52	45.9
10% reduction	44.90	40.80	42.20	37.50	41.00	
25% reduction	37.40	34.00	35.20	31.30	34.10	
40% reduction	30.00	27.20	28.20	25.00	27.30	
25% increase	62.40	56.60	58.70	52.10	56.90	
Indiana	48.58	39.87	46.72	45.10	47.33	45.5
10% reduction	43.70	35.90	42.00	40.60	42.60	
25% reduction	36.40	29.90	35.00	33.80	35.50	
40% reduction	29.10	23.90*	28.00	27.10	28.40	
25% increase	60.70	49.80	58.40	56.40	59.20	
Iowa	47.25	40.72	42.11	32.88	35.34	39.7
10% reduction	42.50	36.60	37.90	29.10	31.80	
25% reduction	35.40	30.50	31.60	24.30	26.50	
40% reduction	28.40	24.40*	25.30	19.40*	21.20*	
25% increase	59.10	50.90	52.60	40.50	44.20	
Kansas	47.53	43.76	45.57	40.98	41.62	43.9
10% reduction	42.80	39.40	40.90	36.90	37.50	
25% reduction	35.60	32.80	34.10	30.70	31.20	
40% reduction	28.50	26.30	27.30	24.60	25.00	
25% increase	59.40	54.70	56.80	57.20	52.00	

Table D.1. (continued)

Year State	1978	1979	1980	1981	1982	1978-1982 Average
	(parts per billion)					
Kentucky	48.73	39.10	44.88	39.16	45.68	43.5
10% reduction	43.90	35.20	40.40	35.20	41.10	
25% reduction	36.50	29.30	33.70	29.40	34.30	
40% reduction	29.20	23.50*	26.90	23.50*	27.40	
25% increase	60.90	48.89	56.10	49.00	57.10	
Louisiana	43.25	35.14	42.22	41.94	49.78	40.5
10% reduction	38.90	31.60	38.00	37.70	35.80	
25% reduction	32.40	26.40	31.70	31.50	29.80	
40% reduction	26.00	21.10*	25.30	25.20	23.90*	
25% increase	54.10	43.90	52.80	52.40	49.70	
Maine	42.82	37.66	34.98	31.41	35.57	36.5
10% reduction	38.50	33.90	31.50	28.30	32.00	
25% reduction	32.10	28.20	26.20	23.60	26.60	
40% reduction	25.70	22.60*	21.00*	18.80*	21.30*	
25% increase	53.50	47.10	43.70	39.30	44.50	
Maryland	44.91	41.82	48.72	49.73	50.73	47.2
10% reduction	40.40	37.60	43.80	44.80	45.70	
25% reduction	33.70	31.40	36.50	37.30	38.00	
40% reduction	26.90	25.10	29.20	29.80	30.40	
25% increase	56.10	52.30	60.90	62.20	63.40	
Massachusetts	41.23	44.17	46.83	44.92	44.25	44.3
10% reduction	37.10	39.80	42.10	40.40	39.80	
25% reduction	30.90	33.10	35.10	33.70	33.20	
40% reduction	24.70	26.50	28.10	27.00	26.60	
25% increase	51.50	55.20	58.50	56.20	55.30	
Michigan	38.05	35.60	37.56	37.93	39.40	37.7
10% reduction	34.20	32.00	33.80	34.10	35.50	
25% reduction	28.50	26.70	28.20	28.40	29.60	
40% reduction	22.80*	21.40*	22.50*	22.80*	23.60*	
25% increase	47.60	44.50	47.00	47.40	49.30	
Minnesota	43.98	36.49	39.25	32.79	33.92	37.3
10% reduction	39.60	32.80	35.30	29.50	30.50	
25% reduction	33.00	27.40	29.40	24.60	25.40	
40% reduction	26.40	21.90*	23.60	19.70*	20.40*	
25% increase	55.00	45.60	49.10	41.00	42.40	

Table D.1. (continued)

Year State	1978	1979	1980	1981	1982	1978-1982 Average
	-------------------	(parts per	billion)	-------------------		
Mississippi	52.35	40.50	49.25	47.20	44.38	46.7
10% reduction	47.10	36.50	44.30	42.50	39.90	
25% reduction	39.30	30.40	36.90	35.40	33.30	
40% reduction	31.40	24.30*	29.60	28.30	26.60	
25% increase	65.40	50.60	61.60	59.00	55.50	
Missouri	52.55	48.51	49.20	37.78	40.24	45.7
10% reduction	47.30	43.70	44.30	34.00	36.20	
25% reduction	39.40	36.40	36.90	28.30	30.20	
40% reduction	31.50	29.10	29.50	22.70*	24.10*	
25% increase	65.70	60.60	61.50	47.20	50.30	
Montana	34.00	49.43	45.00	46.00	46.17	44.1
10% reduction	30.60	44.50	40.50	41.40	41.60	
25% reduction	25.50	37.10	33.80	34.50	34.60	
40% reduction	20.40*	29.70	27.00	27.60	27.70	
25% increase	42.50	61.80	56.30	57.50	57.70	
Nebraska	49.03	42.30	45.17	38.10	33.45	41.6
10% reduction	44.10	38.10	49.70	34.30	30.10	
25% reduction	36.80	31.70	33.90	28.60	25.10	
40% reduction	29.40	25.40	27.10	22.90*	20.10*	
25% increase	61.30	52.90	56.50	47.60	41.80	
Nevada	49.47	53.31	50.84	48.21	48.53	50.1
10% reduction	44.50	48.00	45.80	43.40	43.70	
25% reduction	37.10	40.00	38.10	36.20	36.40	
40% reduction	29.70	32.00	30.50	28.90	29.10	
25% increase	61.80	66.60	63.60	60.30	60.70	
New Hampshire	42.25	40.75	42.58	34.58	37.50	39.5
10% reduction	38.00	36.70	38.30	31.10	33.80	
25% reduction	31.70	30.60	31.90	25.90	28.10	
40% reduction	25.40	24.50	25.50	20.70*	22.50*	
25% increase	52.80	50.90	53.20	43.20	46.90	
New Jersey	42.10	43.60	53.50	50.30	51.30	48.2
10% reduction	37.90	39.20	48.20	45.30	46.20	
25% reduction	31.60	32.70	40.10	37.70	38.50	
40% reduction	25.30	26.20	32.10	30.20	30.80	
25% increase	52.60	54.50	66.90	62.90	64.10	
New Mexico	49.96	47.90	45.87	48.40	47.02	47.8
10% reduction	45.00	43.10	41.30	43.60	42.30	
25% reduction	37.50	35.90	34.40	36.30	35.30	
40% reduction	30.00	28.70	27.50	29.00	28.20	
25% increase	62.50	59.90	57.30	60.50	58.80	

Table D.1. (continued)

Year State	1978	1979	1980	1981	1982	1978-1982 Average
	(parts per billion)					
New York	42.13	40.05	40.91	37.14	36.74	39.4
10% reduction	37.90	36.00	36.80	33.40	33.10	
25% reduction	31.60	30.00	30.70	27.90	27.60	
40% reduction	25.30	24.00*	24.50	22.30*	22.00*	
25% increase	52.70	50.10	51.10	46.40	45.90	
North Carolina	50.83	40.81	54.66	47.94	46.10	49.7
10% reduction	52.90	36.70	49.20	43.10	41.50	
25% reduction	44.10	30.60	41.00	36.00	34.60	
40% reduction	35.30	24.50	32.80	28.80	27.70	
25% increase	73.50	51.00	68.30	59.90	57.60	
North Dakota	37.00	36.00	38.20	37.25	34.21	36.5
10% reduction	33.30	32.40	34.40	33.50	30.80	
25% reduction	27.80	27.00	28.70	27.90	25.70	
40% reduction	22.20*	21.60*	22.90*	22.40*	20.50*	
25% increase	46.30	45.00	47.80	46.60	42.80	
Ohio	45.98	38.42	42.77	41.04	43.88	42.4
10% reduction	41.40	34.60	38.50	36.90	39.50	
25% reduction	34.50	28.80	32.10	30.80	32.90	
40% reduction	27.60	23.10*	25.70	24.60	26.30	
25% increase	57.50	48.00	53.50	51.30	54.90	
Oklahoma	52.37	48.53	47.44	46.54	44.40	47.9
10% reduction	47.10	43.70	42.70	41.90	40.00	
25% reduction	39.30	36.40	35.60	34.90	33.30	
40% reduction	31.40	29.10	28.50	27.90	26.60	
25% increase	65.50	60.70	59.30	58.20	55.50	
Oregon	27.32	30.11	32.06	35.20	38.18	32.6
10% reduction	24.60	27.10	28.90	31.70	34.40	
25% reduction	20.50	22.60	24.00	26.40	28.60	
40% reduction	16.40*	18.10*	19.20*	21.10*	22.90*	
25% increase	34.20	37.60	40.10	44.00	44.70	
Pennsylvania	43.65	38.31	45.11	38.20	40.85	41.2
10% reduction	39.30	34.50	40.60	34.40	36.80	
25% reduction	32.70	28.70	33.80	28.70	30.60	
40% reduction	26.20	23.00*	27.10	22.90*	24.50	
25% increase	54.60	47.90	56.40	47.80	51.10	
Rhode Island	41.33	47.00	53.33	51.66	50.67	48.8
10% reduction	37.20	42.30	48.00	46.50	45.60	
25% reduction	31.00	35.30	40.00	38.70	38.00	
40% reduction	24.80	28.20	32.00	31.00	30.40	
25% increase	51.70	58.80	66.70	64.60	63.30	

Table D.1. (continued)

Year State	1978	1979	1980	1981	1982	1978-1982 Average
	(parts per billion)					
South Carolina	63.52	46.50	53.91	49.10	48.33	52.3
10% reduction	57.20	41.90	48.50	44.20	43.50	
25% reduction	47.60	34.90	40.40	36.80	36.20	
40% reduction	38.10	27.90	32.30	29.50	29.00	
25% increase	79.40	58.10	67.40	61.40	60.40	
South Dakota	42.27	38.74	42.00	37.38	33.30	38.8
10% reduction	38.50	34.90	37.80	33.60	30.10	
25% reduction	32.10	29.10	31.50	28.00	25.00	
40% reduction	25.70	23.20*	25.20	22.40*	20.00*	
25% increase	53.50	48.40	52.50	46.70	41.70	
Tennessee	50.32	35.27	46.66	43.22	48.12	44.7
10% reduction	45.30	31.70	42.00	38.90	43.30	
25% reduction	37.70	26.50	35.00	32.40	36.10	
40% reduction	30.20	21.20*	28.00	25.90	28.90	
25% increase	62.90	44.10	58.30	54.00	60.20	
Texas	42.23	46.16	42.86	43.64	45.57	44.1
10% reduction	38.10	41.50	38.60	39.30	41.00	
25% reduction	31.70	34.60	32.10	32.70	34.20	
40% reduction	25.30	27.70	25.70	26.20	27.30	
25% increase	52.80	57.70	53.60	54.60	57.00	
Utah	49.05	48.39	52.96	49.90	52.40	50.5
10% reduction	44.10	43.60	47.70	44.90	47.20	
25% reduction	36.80	36.30	39.70	37.40	39.30	
40% reduction	29.40	29.00	31.80	29.90	31.40	
25% increase	61.30	60.50	66.20	62.40	65.50	
Vermont	43.07	42.86	43.14	35.36	37.29	40.3
10% reduction	38.80	38.60	38.80	31.80	33.60	
25% reduction	32.30	32.10	32.40	26.50	28.00	
40% reduction	25.80	25.70	25.90	21.20*	22.40*	
25% increase	53.80	53.60	53.90	44.20	46.60	
Virginia	52.90	40.71	54.80	48.16	49.33	49.2
10% reduction	47.60	36.60	49.30	43.30	44.40	
25% reduction	39.70	30.50	41.10	36.10	37.00	
40% reduction	31.70	24.40*	32.90	28.90	29.60	
25% increase	66.10	50.90	68.50	60.20	61.70	
Washington	27.63	31.34	26.49	28.78	28.65	28.6
10% reduction	24.90	28.20	23.80	25.90	25.80	
25% reduction	20.70	23.50	19.90	21.60	21.50	
40% reduction	16.60*	18.80*	15.90*	17.30*	17.20*	
25% increase	34.50	39.20	33.10	36.00	35.80	

Table D.1. (continued)

Year State	1978	1979	1980	1981	1982	1978-1982 Average
	(parts per billion)					
West Virginia	41.77	37.91	44.14	39.05	41.10	40.8
10% reduction	37.60	34.10	39.70	35.10	37.00	
25% reduction	31.30	28.40	33.10	29.30	30.80	
40% reduction	25.10	22.70*	26.50	23.40*	24.70	
25% increase	52.20	47.40	55.20	48.80	51.40	
Wisconsin	45.81	43.50	40.46	38.19	38.55	41.3
10% reduction	41.20	39.20	36.40	34.40	34.70	
25% reduction	34.40	32.70	30.30	28.60	28.90	
40% reduction	27.50	26.20	24.30	22.90*	23.10*	
25% increase	57.30	54.50	50.60	47.70	48.20	
Wyoming	46.31	50.75	47.56	48.83	49.71	48.6
10% reduction	41.70	45.70	42.80	43.90	44.70	
25% reduction	34.70	38.10	35.70	36.60	37.30	
40% reduction	27.80	30.50	28.50	29.30	29.80	
25% increase	57.90	63.40	59.50	61.00	62.10	

* Indicates that the reduced ozone level falls below the 25 ppb background level reported in Heck et al. (1984a).

[a] Source: J. Reagan (1984) and 1982 NCLAN Annual Report (Heck et al. 1983).

Table D.2. April and May average ozone levels for winter wheat producing states a/

Year State	1978	1979	1980	1978-80 Average
	----------------	(ppb)	----------------	----------------
Arizona				
Ambient	N.A.	47.90	44.00	46.00
10% reduction	N.A.	43.10	39.60	
25% reduction	N.A.	35.90	29.70	
40% reduction	N.A.	28.70	26.40	
25% increase	N.A.	59.90	55.00	
Arkansas				
Ambient	42.31	50.85	44.74	46.00
10% reduction	38.10	45.80	40.30	41.40
25% reduction	37.10	38.10	33.60	36.30
40% reduction	25.40	30.50	26.80	27.60
25% increase	52.90	63.60	55.90	57.50
California				
Ambient	N.A.	45.64	43.39	44.50
10% reduction	N.A.	44.10	39.10	41.60
25% reduction	N.A.	34.20	32.50	33.40
40% reduction	N.A.	27.40	26.00	26.70
25% increase	N.A.	57.10	54.20	55.70
Colorado				
Ambient	47.44	48.23	46.48	47.40
10% reduction	42.70	43.40	41.80	
25% reduction	35.60	36.20	34.90	
40% reduction	28.50	28.90	27.90	
25% increase	59.30	60.30	58.10	
Idaho				
Ambient	N.A.	45.63	46.69	46.20
10% reduction	N.A.	41.10	42.00	
25% reduction	N.A.	34.20	35.00	
40% reduction	N.A.	27.40	28.00	
25% increase	N.A.	57.00	58.40	
Illinois				
Ambient	42.92	34.66	41.35	39.60
10% reduction	38.60	31.20	37.50	
25% reduction	32.20	26.00	31.00	
40% reduction	25.80	20.80	24.80	
25% increase	53.70	43.30	51.70	
Indiana				
Ambient	40.36	32.68	33.55	35.50
10% reduction	36.30	29.40	30.20	
25% reduction	30.30	24.50	25.20	
40% reduction	24.20	19.60	20.10	
25% increase	50.50	40.90	41.90	

Table D.2. (continued)

State \ Year	1978	1979	1980	1978-80 Average
	(ppb)			
Kansas				
Ambient	39.00	42.04	38.32	39.80
10% reduction	35.10	37.80	34.40	
25% reduction	29.30	31.50	28.70	
40% reduction	23.40	25.20	22.90	
25% increase	48.80	52.60	47.80	
Kentucky				
Ambient	39.60	37.07	38.88	38.50
10% reduction	35.60	33.40	35.00	
25% reduction	29.70	27.80	29.20	
40% reduction	23.80	22.20	23.30	
25% increase	49.50	46.30	48.60	
Michigan				
Ambient	37.00	30.10	34.30	33.80
10% reduction	33.30	27.10	30.90	
25% reduction	27.80	20.30	23.20	
40% reduction	22.20	18.10	20.60	
25% increase	46.30	37.60	42.90	
Missouri				
Ambient	38.39	47.27	46.56	44.00
10% reduction	34.60	42.50	41.90	
25% reduction	28.80	35.50	34.90	
40% reduction	23.00	28.40	27.90	
25% increase	48.00	59.10	58.20	
Montana				
Ambient	28.00	41.13	46.50	38.50
10% reduction	25.20	37.00	41.90	
25% reduction	21.00	30.80	34.90	
40% reduction	16.80	24.70	27.90	
25% increase	35.00	51.40	58.10	
Nebraska				
Ambient	42.38	42.83	41.72	42.30
10% reduction	38.10	38.50	37.50	
25% reduction	31.80	32.10	31.30	
40% reduction	25.40	25.70	25.00	
25% increase	53.00	53.50	52.20	
New Mexico				
Ambient	47.00	41.60	41.70	43.40
10% reduction	42.30	37.40	37.50	
25% reduction	35.30	31.20	31.30	
40% reduction	28.20	25.00	25.00	
25% increase	58.80	52.00	52.10	

Table D.2. (continued)

Year State	1978	1979	1980	1978-80 Average
	(ppb)			
New York				
Ambient	42.13	36.68	38.72	39.20
10% reduction	37.90	33.00	34.80	
25% reduction	31.60	27.50	29.00	
40% reduction	25.30	22.00	23.20	
25% increase	52.70	45.90	48.40	
North Carolina				
Ambient	45.68	42.37	50.08	46.00
10% reduction	41.10	38.10	45.10	
25% reduction	34.30	31.80	37.60	
40% reduction	27.40	25.40	30.00	
25% increase	57.10	53.00	62.60	
Ohio				
Ambient	39.89	36.32	32.30	36.20
10% reduction	35.90	32.70	29.10	
25% reduction	29.90	27.20	24.20	
40% reduction	23.90	21.80	19.40	
25% increase	49.90	45.40	40.40	
Oklahoma				
Ambient	40.01	42.76	32.55	38.40
10% reduction	36.00	38.50	29.30	
25% reduction	30.00	32.10	24.40	
40% reduction	24.00	25.70	19.50	
25% increase	50.00	53.50	40.70	
Pennsylvania				
Ambient	42.14	34.20	39.43	38.50
10% reduction	37.90	30.80	35.50	
25% reduction	31.60	25.70	29.60	
40% reduction	25.30	20.50	23.70	
25% increase	52.70	42.80	49.30	
South Carolina				
Ambient	48.47	46.59	52.31	49.10
10% reduction	43.60	41.90	47.10	
25% reduction	36.40	34.90	39.20	
40% reduction	29.10	28.00	31.40	
25% increase	60.60	58.20	65.40	
South Dakota				
Ambient	37.10	37.20	39.80	38.00
10% reduction	33.40	33.50	35.80	
25% reduction	27.80	27.90	29.90	
40% reduction	22.30	22.30	23.90	
25% increase	46.40	46.50	49.80	

Table D.2. (continued)

Year State	1978	1979	1980	1978-80 Average
	(ppb)			
Tennessee				
Ambient	42.22	36.05	44.05	40.80
10% reduction	38.00	32.40	39.60	
25% reduction	31.70	27.00	33.00	
40% reduction	25.30	21.60	26.40	
25% increase	52.80	45.10	55.10	
Texas				
Ambient	41.80	39.61	39.60	40.30
10% reduction	37.60	35.60	35.60	
25% reduction	31.40	29.70	29.70	
40% reduction	25.10	23.80	23.80	
25% increase	52.30	49.50	49.50	
Wyoming				
Ambient	45.74	47.63	46.74	46.70
10% reduction	41.20	42.90	42.10	
25% reduction	34.30	35.70	35.10	
40% reduction	27.40	28.60	28.00	
25% increase	57.20	59.50	58.40	

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[a] Winter wheat producing states (e.g., Washington, Oregon) with winter-spring ambient ozone concentrations near or below the 25 parts per billion reported as background by Heck et al. (1982) are not listed in the table. Reductions below such levels are not feasible. These states are included in the economic assessment, however, as shown in the yield adjustments portrayed in Tables D.16 through D.35, by using a minimum ozone value of 22 ppb.

Table D.3. Predicted soybean yield adjustments by state, year and ozone assumption a/

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 5 year Ave.
Alabama						
10% reduction	2.80	2.18	2.57	2.59	2.80	2.59
25% reduction	7.02	5.45	6.42	6.47	7.02	6.48
40% reduction	11.22	8.67	10.42	10.32	11.21	10.37
25% increase	- 6.92	- 5.45	- 6.36	- 6.41	- 6.91	- 6.41
Arkansas						
10% reduction	3.23	2.78	2.87	2.61	2.47	2.79
25% reduction	8.12	6.96	7.20	6.53	6.17	7.00
40% reduction	13.01	11.13	11.51	10.42	9.85	11.18
25% increase	- 7.91	- 6.86	- 7.08	- 6.46	- 6.13	- 6.89
Delaware						
10% reduction	2.30	2.43	1.85	3.05	2.70	2.47
25% reduction	5.74	6.08	4.60	7.65	6.77	6.17
40% reduction	9.15	9.69	7.31	12.24	10.81	9.84
25% increase	- 5.73	- 6.04	- 4.64	- 7.49	- 6.68	- 6.12
Florida						
10% reduction	2.27	1.77	1.81	2.27	2.03	2.03
25% reduction	5.66	4.39	4.49	5.56	5.06	5.03
40% reduction	9.01	6.97	7.13	0.01	8.05	8.03
25% increase	- 5.65	- 4.44	- 4.54	- 5.65	- 5.08	- 5.07
Georgia						
10% reduction	3.09	2.33	2.56	2.49	2.48	2.59
25% reduction	7.76	5.81	6.39	6.23	6.19	6.48
40% reduction	12.43	9.26	10.19	9.93	9.87	10.34
25% increase	- 7.59	- 5.79	- 6.33	- 6.18	- 6.15	- 6.41
Illinois						
10% reduction	2.77	2.45	2.56	2.22	2.47	2.49
25% reduction	6.93	6.13	6.41	5.53	6.17	6.23
40% reduction	11.07	9.77	10.22	8.79	9.83	9.94
25% increase	- 6.83	- 6.09	- 6.35	- 5.52	- 6.13	- 6.18
Indiana						
10% reduction	2.67	2.10	2.55	2.44	2.59	2.47
25% reduction	6.69	5.23	6.37	6.10	6.48	6.17
40% reduction	10.69	8.31	10.17	9.72	10.34	9.85
25% increase	- 6.61	- 5.24	- 6.32	- 6.06	- 6.41	- 6.13
Iowa						
10% reduction	2.58	2.15	2.24	1.62	1.81	2.08
25% reduction	6.46	5.37	5.60	4.03	4.50	5.19
40% reduction	10.31	8.54	8.91	6.39	7.14	8.26
25% increase	- 6.40	- 5.37	- 5.59	- 4.09	- 4.54	- 5.20

Table D.3. (continued)

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 5 Year Ave.
Kansas						
10% reduction	2.60	2.35	2.47	2.17	2.21	2.36
25% reduction	6.51	5.87	6.16	5.41	5.51	5.89
40% redution	10.39	9.35	9.82	8.60	8.78	9.39
25% increase	- 6.45	- 5.85	- 6.12	- 5.41	- 5.51	- 5.87
Kentucky						
10% reduction	2.68	2.05	2.43	2.05	2.48	2.34
25% reduction	6.72	5.10	6.06	5.11	6.20	5.84
40% reduction	10.73	8.11	9.66	8.12	9.88	9.30
25% increase	- 6.64	- 5.12	- 6.03	- 5.13	- 6.15	- 5.81
Louisiana						
10% reduction	2.32	1.80	2.25	2.23	2.09	2.14
25% reduction	5.79	4.46	5.61	5.57	5.21	5.33
40% reduction	9.21	7.09	8.94	8.86	8.29	8.48
25% increase	- 5.77	- 4.51	- 5.61	- 5.56	- 5.22	- 5.33
Maryland						
10% reduction	2.43	2.22	2.68	2.75	2.82	2.58
25% reduction	6.06	5.55	6.72	6.89	7.07	6.46
40% reduction	9.67	8.83	10.73	11.01	11.30	10.31
25% increase	- 6.03	- 5.54	- 6.64	- 6.80	- 6.96	- 6.39
Michigan						
10% reduction	1.98	1.82	1.95	1.97	2.07	1.96
25% reduction	4.93	4.54	4.85	4.91	5.15	4.88
40% reduction	7.83	7.20	7.71	7.80	8.19	7.75
25% increase	- 4.96	- 4.58	- 4.88	- 4.94	- 5.17	- 4.91
Minnesota						
10% reduction	2.37	1.88	2.06	1.65	1.72	1.94
25% reduction	5.91	4.68	5.12	4.10	4.27	4.82
40% reduction	9.41	7.43	8.15	6.50	6.78	7.65
25% increase	- 5.88	- 4.72	- 5.14	- 4.15	- 4.32	- 4.82
Mississippi						
10% reduction	2.93	2.14	2.72	2.58	2.39	2.55
25% reduction	7.35	5.33	6.81	6.46	5.98	6.41
40% reduction	11.76	8.48	10.88	10.30	9.52	10.19
25% increase	- 7.22	- 5.34	- 6.72	- 6.39	- 5.95	- 6.32
Missouri						
10% reduction	2.95	2.67	2.72	1.96	2.12	2.48
25% reduction	7.39	6.68	6.80	4.89	5.29	6.21
40% reduction	11.82	10.67	10.86	7.76	8.41	9.90
25% increase	- 7.25	- 6.60	- 6.71	- 4.91	- 5.30	- 6.15

Table D.3. (continued)

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 5 Year Ave.
Nebraska						
10% reduction	2.71	2.26	2.45	1.98	1.69	2.22
25% reduction	6.77	5.63	6.11	4.94	4.20	5.53
40% reduction	10.81	8.96	9.74	7.85	6.66	8.80
25% increase	- 6.69	- 5.62	- 6.07	- 4.96	- 4.25	- 5.52
New Jersey						
10% reduction	2.24	2.34	3.01	2.79	2.86	2.65
25% reduction	5.59	5.84	7.56	6.99	7.17	6.63
40% reduction	8.90	9.31	12.10	11.17	11.46	10.59
25% increase	- 5.59	- 5.82	- 7.41	- 6.89	- 7.05	- 6.55
New York						
10% reduction	2.24	2.11	2.16	1.92	1.90	2.07
25% reduction	5.60	5.26	5.40	4.78	4.72	5.15
40% reduction	8.91	8.36	8.59	7.60	7.49	8.19
25% increase	- 5.59	- 5.27	- 5.40	- 4.82	- 4.75	- 5.17
North Carolina						
10% reduction	3.39	2.16	3.09	2.63	2.51	2.76
25% reduction	8.52	5.38	7.75	6.58	6.27	6.90
40% reduction	13.68	8.56	12.43	10.51	9.99	11.03
25% increase	- 8.28	- 5.38	- 7.60	- 6.51	- 6.22	- 6.80
North Dakota						
10% reduction	1.91	1.85	1.99	1.93	1.74	1.88
25% reduction	4.76	4.60	4.95	4.80	4.32	4.69
40% reduction	7.56	7.31	7.87	7.63	6.85	7.44
25% increase	- 4.79	- 4.64	- 4.98	- 4.83	- 4.37	- 4.72
Ohio						
10% reduction	2.50	2.00	2.29	2.17	2.36	2.26
25% reduction	6.25	4.99	5.71	5.42	5.89	5.65
40% reduction	9.96	7.93	9.08	8.62	9.39	9.00
25% increase	- 6.20	- 5.01	- 5.69	- 5.42	- 5.87	- 5.64
Oklahoma						
10% reduction	2.93	2.67	2.60	2.54	2.39	2.63
25% reduction	7.36	6.68	6.50	6.34	5.98	6.57
40% reduction	11.77	10.67	10.37	10.12	9.53	10.49
25% increase	- 7.22	- 6.61	- 6.43	- 6.29	- 5.95	- 6.50
Pennsylvania						
10% reduction	2.34	2.00	2.44	1.99	2.16	2.19
25% reduction	5.85	4.97	6.10	4.95	5.39	5.45
40% reduction	9.32	7.90	9.72	7.87	8.57	8.68
25% increase	- 5.83	- 5.00	- 6.06	- 4.98	- 5.39	- 5.45

Table D.3. (continued)

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
South Carolina						
10% reduction	3.73	2.53	3.04	2.71	2.66	2.93
25% reduction	9.39	6.34	7.63	6.78	6.65	7.36
40% reduction	15.11	10.11	12.22	10.83	10.62	11.78
25% increase	- 9.05	- 6.28	- 7.47	- 6.70	- 6.57	- 7.21
South Dakota						
10% reduction	2.25	2.02	2.24	1.94	1.69	2.03
25% reduction	5.62	5.04	5.58	4.82	4.19	5.05
40% reduction	8.95	8.01	8.88	7.66	6.64	8.03
25% increase	- 5.61	- 5.06	- 5.57	- 4.85	- 4.24	- 5.07
Tennessee						
10% reduction	2.79	1.80	2.54	2.32	2.64	2.42
25% reduction	7.00	4.49	6.36	5.78	6.61	6.05
40% reduction	11.18	7.12	10.15	9.21	10.56	9.64
25% increase	- 6.89	- 4.53	- 6.31	- 5.76	- 6.54	- 6.01
Texas						
10% reduction	2.25	2.51	2.29	2.34	2.47	2.37
25% reduction	5.62	6.28	5.72	5.85	6.18	5.92
40% reduction	8.94	10.01	9.11	9.32	9.85	9.45
25% increase	- 5.61	- 6.23	- 5.71	- 5.83	- 6.13	- 5.90
Virgina						
10% reduction	2.97	2.15	3.10	2.65	2.73	2.72
25% reduction	7.45	5.36	7.79	6.62	6.82	6.81
40% reduction	11.92	8.53	12.48	10.57	10.90	10.88
25% increase	- 7.31	- 5.37	- 7.62	- 6.55	- 6.73	- 6.72
Wisconsin						
10% reduction	2.49	2.34	2.14	1.99	2.01	2.20
25% reduction	6.22	5.84	5.32	4.95	5.01	5.47
40% reduction	9.91	9.31	8.47	7.87	7.96	8.70
25% increase	- 6.16	- 5.82	- 5.33	- 4.98	- 5.03	- 5.47

[a] Predicted yield adjustments based on Weibull response model estimated from a pooled set of 16 cultivar experiments (Heck et al., 1984b; W.W. Cure, personal communication).

Table D.4. Predicted corn yield adjustments by state, year and ozone assumption a/

State and Ozone	Year					1978-82
Assumption	1978	1979	1980	1981	1982	Average
Alabama						
10% reduction	.55	.27	.43	.44	.55	.45
25% reduction	1.13	.55	.88	.90	1.13	.92
40% reduction	1.50	.74	1.15	1.19	1.50	1.22
25% increase	-2.12	-1.05	-1.64	-1.68	-2.11	-1.72
Arizona						
10% reduction	.39	.30	.60	.46	.40	.43
25% reduction	.79	.62	1.22	.94	.81	.88
40% reduction	1.04	.81	1.60	1.23	1.07	1.15
25% increase	-1.50	-1.17	-2.28	-1.79	-1.56	-1.66
Arkansas						
10% reduction	.83	.54	.59	.45	.38	.56
25% reduction	1.69	1.10	1.21	.92	.78	1.14
40% reduction	2.21	1.44	1.58	1.20	1.03	1.49
25% increase	-3.14	-2.07	-2.26	-1.72	-1.50	-2.14
California						
10% reduction	.42	.58	.61	.55	.41	.51
25% reduction	.87	1.18	1.26	1.13	.83	1.05
40% reduction	1.13	1.55	1.64	1.47	1.09	1.38
25% increase	-1.65	-2.26	-2.41	-2.15	-1.58	-2.01
Colorado						
10% reduction	.55	.58	.57	.47	.55	.54
25% reduction	1.12	1.20	1.16	.95	1.12	1.11
40% reduction	1.46	1.56	1.52	1.25	1.47	1.45
25% increase	-2.14	-2.29	-2.23	-1.82	-2.15	-2.12
Connecticut						
10% reduction	.38	.51	.95	.57	.59	.60
25% reduction	.78	1.05	1.93	1.17	1.20	1.23
40% reduction	1.03	1.38	2.52	1.53	1.57	1.60
25% increase	-1.49	-2.01	-3.60	-2.24	-2.29	-2.33
Delaware						
10% reduction	.31	.37	.17	.70	.50	.41
25% reduction	.64	.75	.34	1.43	1.02	.84
40% reduction	.84	.99	.45	1.87	1.33	1.10
25% increase	-1.22	-1.43	- .65	-2.68	-1.90	-1.58
Florida						
10% reduction	.30	.15	.16	.30	.22	.23
25% reduction	.62	.30	.32	.62	.45	.46
40% reduction	.81	.40	.42	.81	.59	.60
25% increase	-1.17	- .57	- .61	-1.17	- .85	- .87

Table D.4. (continued)

State and Ozone Assumption	Year					1978-82 Average
	1978	1979	1980	1981	1982	
Georgia						
10% reduction	.73	.32	.42	.39	.39	.45
25% reduction	1.49	.66	.87	.81	.79	.92
40% reduction	1.05	.87	1.13	1.06	1.04	1.21
25% increase	-2.78	-1.26	-1.65	-1.53	-1.51	-1.75
Idaho						
10% reduction	N.A.	.57	.39	.45	.46	.47
25% reduction	N.A.	1.17	.80	.92	.94	.96
40% reduction	N.A.	1.53	1.04	1.20	1.23	1.25
25% increase	N.A.	-2.19	-1.52	-1.71	-1.73	-1.79
Illinois						
10% reduction	.53	.38	.43	.28	.38	.40
25% reduction	1.09	.77	.87	.58	.79	.82
40% reduction	1.42	1.01	1.14	.75	1.03	1.07
25% increase	-2.07	-1.47	-1.66	-1.09	-1.49	-1.56
Indiana						
10% reduction	.48	.24	.42	.37	.44	.39
25% reduction	.99	.49	.86	.76	.90	.80
40% reduction	1.29	.64	1.13	.99	1.18	1.05
25% increase	-1.88	- .93	-1.61	-1.43	-1.68	-1.51
Iowa						
10% reduction	.44	.26	.29	.12	.16	.25
25% reduction	.90	.53	.60	.24	.32	.52
40% reduction	1.17	.69	.78	.31	.42	.68
25% increase	-1.70	-1.00	-1.12	- .45	- .61	- .98
Kansas						
10% reduction	.45	.33	.38	.26	.28	.34
25% reduction	.91	.68	.78	.54	.57	.70
40% reduction	1.20	.89	1.02	.71	.75	.91
25% increase	-1.74	-1.30	-1.49	-1.03	-1.09	-1.33
Kentucky						
10% reduction	.49	.22	.36	.23	.39	.34
25% reduction	1.00	.46	.75	.46	.80	.69
40% reduction	1.31	.60	.98	.61	1.04	.91
25% increase	1.90	.87	1.42	.87	1.51	1.32
Louisana						
10% reduction	.32	.15	.29	.29	.24	.26
25% reduction	.66	.32	.60	.59	.49	.53
40% reduction	.86	.41	.79	.77	.64	.69
25% increase	1.24	.59	1.13	1.11	.92	1.00
Maine						
10% reduction	.31	.20	.15	.10	.16	.18
25% reduction	.63	.40	.31	.21	.33	.38
40% reduction	.83	.53	.41	.28	.43	.49
25% reduction	-1.20	- .76	- .59	- .40	- .62	- .71

Table D.4. (continued)

State and Ozone Assumption	Year					1978-82 Average
	1978	1979	1980	1981	1982	
Maryland						
10% reduction	.37	.28	.49	.52	.56	.44
25% reduction	.75	.58	1.00	1.07	1.15	.91
40% reduction	.98	.76	1.30	1.40	1.50	1.99
25% increase	-1.42	-1.10	-1.90	-2.00	-2.15	-1.71
Massachusetts						
10% reduction	.27	.34	.42	.37	.35	.35
25% reduction	.55	.71	.87	.75	.71	.72
40% reduction	.73	.92	1.14	.98	.93	.94
25% increase	-1.05	-1.34	-1.65	-1.42	-1.35	-1.36
Michigan						
10% reduction	.20	.16	.19	.20	.23	.20
25% reduction	.42	.33	.40	.41	.47	.41
40% reduction	.55	.43	.52	.54	.62	.53
25% increase	- .79	- .62	- .75	- .78	- .89	- .77
Minnesota						
10% reduction	.34	.18	.23	.12	.14	.20
25% reduction	.70	.36	.47	.25	.28	.41
40% reduction	.91	.47	.61	.32	.36	.54
25% increase	-1.32	- .68	- .88	- .47	- .53	- .78
Mississippi						
10% reduction	.63	.25	.51	.44	.35	.43
25% reduction	1.28	.52	1.04	.89	.72	.89
40% reduction	1.68	.68	1.35	1.17	.94	1.16
25% increase	-2.39	- .99	-1.98	-1.70	-1.36	-1.68
Missouri						
10% reduction	.64	.48	.50	.20	.25	.41
25% reduction	1.30	.98	1.03	.62	.78	
40% reduction	1.70	1.28	1.35	.62	.78	1.15
25% increase	-2.43	-1.87	-1.97	- .77	- .96	-1.60
Montana						
10% reduction	.14	.51	.37	.40	.40	.36
25% reduction	.28	1.05	.75	.82	.83	.75
40% reduction	.37	1.37	.99	1.07	1.08	.97
25% increase	- .53	-2.00	-1.43	-1.55	-1.57	-1.42
Nebraska						
10% reduction	.50	.30	.37	.20	.13	.30
25% reduction	1.02	.61	.76	.42	.27	.62
40% reduction	1.33	.79	1.00	.55	.35	.80
25% increase	-1.94	-1.15	-1.45	- .79	- .50	-1.17

Table D.4. (continued)

State and Ozone Assumption	Year					1978-82 Average
	1978	1979	1980	1981	1982	
Nevada						
10% reduction	.51	.67	.57	.47	.48	.54
25% reduction	1.05	1.37	1.16	.96	.98	1.10
40% reduction	1.38	1.79	1.51	1.26	1.29	1.44
25% increase	-1.96	-2.55	-2.17	-1.83	-1.87	-2.08
New Hampshire						
10% reduction	.29	.26	.30	.15	.19	.24
25% reduction	.60	.53	.62	.30	.40	.49
40% reduction	.79	.70	.81	.39	.52	.64
25% increase	-1.55	-1.01	-1.18	- .56	- .75	- .93
New Jersey						
10% reduction	.29	.33	.68	.54	.58	.49
25% reduction	.60	.68	1.39	1.12	1.20	.99
40% reduction	.78	.88	1.81	1.46	1.56	1.30
25% increase	-1.13	-1.28	-2.59	-2.09	-2.23	-1.86
New Mexico						
10% reduction	.53	.46	.39	.48	.43	.46
25% reduction	1.09	.94	.81	.97	.88	.94
40% reduction	1.42	1.23	1.06	1.27	1.15	1.23
25% increase	-2.08	-1.79	-1.53	-1.86	-1.68	-1.79
New York						
10% reduction	.29	.24	.26	.19	.18	.23
25% reduction	.60	.50	.54	.38	.37	.48
40% reduction	.78	.66	.71	.50	.48	.63
25% increase	-1.13	- .95	-1.02	- .73	- .70	- .91
North Carolina						
10% reduction	.95	.26	.73	.46	.40	.56
25% reduction	1.93	.53	1.49	.94	.82	1.14
40% reduction	2.52	.70	1.95	1.23	1.07	1.50
25% increase	-3.60	-1.01	-2.78	-1.79	-1.56	-2.15
North Dakota						
10% reduction	.18	.17	.21	.19	.14	.18
25% reduction	.38	.34	.42	.39	.29	.36
40% reduction	.50	.45	.55	.51	.38	.48
25% increase	- .72	- .65	- .80	- .73	- .54	- .69
Ohio						
10% reduction	.40	.21	.31	.27	.34	.30
25% reduction	.81	.43	.63	.55	.69	.62
40% reduction	1.06	.57	.83	.71	.90	.81
25% increase	-1.55	- .82	-1.20	-1.03	-1.31	-1.18

Table D.4. (continued)

State and Ozone Assumption	Year					1978-82 Average
	1978	1979	1980	1981	1982	
Oklahoma						
10% reduction	.63	.48	.44	.41	.35	.46
25% reduction	1.29	.98	.91	.85	.72	.95
40% reduction	1.68	1.29	1.19	1.11	.94	1.24
25% increase	-2.46	-1.87	-1.73	-1.62	-1.37	-1.81
Oregon						
10% reduction	.06	.09	.11	.15	.21	.13
25% reduction	.13	.18	.23	.32	.42	.26
40% reduction	.17	.24	.30	.42	.55	.34
25% increase	- .24	- .34	- .43	- .60	- .80	- .48
Pennsylvania						
10% reduction	.33	.21	.37	.21	.26	.28
25% reduction	.68	.43	.76	.42	.54	.57
40% reduction	.89	.56	1.00	.55	.70	.74
25% increase	-1.29	- .81	-1.45	- .80	-1.02	-1.07
Rhode Island						
10% reduction	.27	.43	.67	.60	.56	.51
25% reduction	.56	.88	1.37	1.23	1.14	1.04
40% reduction	.73	1.15	1.79	1.60	1.50	1.35
25% increase	-1.06	-1.67	-2.55	-2.29	-2.14	-1.94
South Carolina						
10% reduction	1.24	.41	.70	.50	.47	.66
25% reduction	2.52	.85	1.42	1.02	.97	1.36
40% reduction	3.29	1.11	1.86	1.34	1.27	1.77
25% increase	-4.69	-1.59	-2.66	-1.95	-1.85	-2.55
South Dakota						
10% reduction	.30	.22	.29	.19	.13	.22
25% reduction	.61	.45	.59	.39	.26	.46
40% reduction	.79	.58	.77	.51	.35	.60
25% increase	-1.15	- .84	-1.12	- .74	- .50	- .87
Tennessee						
10% reduction	.55	.16	.42	.32	.47	.38
25% reduction	1.12	.32	.86	.65	.95	.78
40% reduction	1.46	.42	1.12	.86	1.25	1.02
25% increase	-2.13	- .60	-1.63	-1.24	-1.82	-1.49
Texas						
10% reduction	.29	.40	.31	.33	.38	.34
25% reduction	.60	.83	.64	.68	.79	.71
40% reduction	.79	1.08	.83	.89	1.03	.92
25% increase	-1.14	-1.57	-1.21	-1.28	-1.50	-1.34

Table D.4. (continued)

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
Utah						
10% reduction	.50	.48	.65	.53	.63	.56
25% reduction	1.02	.97	1.34	1.08	1.29	1.14
40% reduction	1.34	1.27	1.75	1.42	1.68	1.49
25% increase	-1.95	-1.86	-2.49	-2.02	-2.41	-2.15
Vermont						
10% reduction	.32	.31	.32	.16	.19	.26
25% reduction	.65	.64	.65	.32	.39	.53
40% reduction	.85	.83	.85	.42	.51	.69
25% increase	-1.23	-1.21	-1.23	- .61	- .74	-1.00
Virginia						
10% reduction	.65	.26	.74	.47	.51	.52
25% reduction	1.33	.53	1.51	.96	1.04	1.07
40% reduction	1.74	.69	1.97	1.25	1.36	1.40
25% increase	-2.48	-1.00	-2.82	-1.82	-1.99	-2.02
Washington						
10% reduction	.07	.10	.06	.08	.07	.08
25% reduction	.14	.21	.12	.16	.15	.15
40% reduction	.18	.28	.15	.20	.20	.20
25% increase	- .25	- .40	- .22	- .29	- .29	- .29
West Virginia						
10% reduction	.28	.20	.34	.22	.27	.26
25% reduction	.58	.41	.70	.46	.55	.54
40% reduction	.76	.54	.92	.60	.72	.71
25% increase	-1.10	- .78	-1.34	- .87	-1.04	-1.02
Wisconsin						
10% reduction	.39	.33	.25	.21	.21	.28
25% reduction	.80	.67	.52	.42	.44	.57
40% reduction	1.05	.88	.68	.55	.57	.75
25% increase	-1.53	-1.28	- .98	- .80	- .83	-1.08
Wyoming						
10% reduction	.41	.56	.45	.49	.52	.49
25% reduction	.83	1.15	.92	1.01	1.07	1.00
40% reduction	1.09	1.50	1.20	1.31	1.40	1.30
25% increase	-1.59	-2.15	-1.74	-1.88	-2.00	-1.87

[a] Predicted yield adjustments based on Weibull response model of three pooled corn cultivars.

Table D.5. Predicted southeast cotton (nonirrigated) yield adjustments by state, year and ozone assumptions a/

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
Alabama						
10% reduction	3.09	1.83	2.57	2.61	3.09	2.64
25% reduction	6.93	4.07	5.74	5.84	6.93	5.90
40% reduction	9.84	5.73	8.11	8.25	9.82	8.35
25% increase	-9.48	-5.55	-8.25	-8.07	-9.47	- 8.16
Arkansas						
10% reduction	4.19	3.04	3.26	2.66	2.37	3.10
25% reduction	9.45	6.82	7.32	5.95	5.30	6.97
40% reduction	13.45	9.66	10.37	8.41	7.47	9.87
25% indrease	-12.54	-9.34	-9.95	-8.22	-7.37	-9.48
Florida						
10% reduction	1.98	1.17	1.23	1.98	1.57	1.59
25% reduction	4.40	2.58	2.72	4.41	3.48	3.52
40% reduction	6.20	3.63	3.81	6.21	4.90	4.95
25% increase	-6.20	-3.72	-3.89	-6.20	-4.95	-4.99
Georgia						
10% reduction	3.82	2.08	2.55	2.42	2.37	3.65
25% reduction	8.59	4.65	5.59	5.39	5.31	5.91
40% reduction	12.21	6.57	8.04	7.61	7.51	8.39
25% increase	-11.52	-6.53	-7.88	-7.48	-7.41	-8.16
Kentucky						
10% reduction	2.82	1.58	2.28	1.60	2.39	2.13
25% reduction	6.32	3.54	5.09	3.55	5.33	4.77
40% reduction	8.95	4.98	7.18	5.00	7.53	6.73
25% increase	-8.70	-5.03	-7.10	-5.05	-7.42	-6.66
Louisiana						
10% reduction	2.07	1.21	1.94	1.92	1.67	1.76
25% reduction	4.61	2.68	4.33	4.26	3.71	3.92
40% reduction	6.51	3.76	6.10	6.00	5.21	5.52
25% increase	-6.47	-3.84	-6.10	-5.99	-5.25	- 5.53
Mississippi						
10% reduction	3.41	1.74	2.90	2.61	2.21	2.57
25% reduction	7.66	3.88	6.51	5.81	4.93	5.76
40% reduction	10.86	5.47	9.21	8.22	6.97	8.15
25% increase	-10.37	-5.50	-8.93	-8.04	-6.91	-7.95
Missouri						
10% reduction	3.44	2.78	2.90	1.46	1.72	2.46
25% reduction	7.74	6.24	6.48	3.24	3.81	5.50
40% reduction	10.97	8.84	9.18	4.55	5.37	7.78
25% increase	-10.47	-8.60	-8.91	-4.61	-5.40	7.60

Table D.5. (continued)

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
North Carolina						
10% reduction	4.63	1.78	3.82	2.71	2.43	3.07
25% reduction	10.48	3.96	8.59	6.05	5.46	6.91
40% reduction	14.94	5.58	12.21	8.57	7.71	9.80
25% increase	-13.74	-5.60	-11.52	-8.36	-7.59	-9.36
South Carolina						
10% reduction	5.67	2.50	3.68	2.88	2.76	3.50
25% reduction	12.91	5.58	8.29	6.46	6.18	7.88
40% reduction	18.28	7.89	11.76	9.31	8.75	11.20
25% increase	-16.48	-7.75	-11.13	-8.86	-8.52	-10.45
Tennessee						
10% reduction	3.08	1.21	2.52	2.07	2.73	2.32
25% reduction	6.89	2.69	5.63	4.61	6.12	5.19
40% reduction	9.76	3.80	7.97	6.49	8.65	7.33
25% increase	-10.39	-3.88	-7.82	-6.45	-8.43	-7.39
Virginia						
10% reduction	3.50	1.77	3.84	2.73	2.91	2.95
25% reduction	7.87	3.93	8.55	6.13	6.52	6.60
40% reduction	11.17	5.54	12.30	8.67	9.25	9.39
25% increase	-10.64	-5.57	-11.59	-8.45	-8.97	-9.04
West Virginia						
10% reduction	1.89	1.47	2.19	1.58	1.81	1.79
25% reduction	4.21	3.26	4.87	3.53	4.03	3.98
40% reduction	5.93	4.59	6.87	4.96	5.68	5.61
25% increase	-5.94	-4.66	-6.81	-5.02	-5.70	-5.63

[a] Predicted yield adjustments based on Weibull response model of Stoneville 213 cultivars.

Table D.6. Predicted cotton yield adjustments by state, year and ozone assumption for irrigated cotton (Acala SJ-2, 1981)

State and Ozone Assumption	Year					1978-82 Average
	1978	1979	1980	1981	1982	
Arizona						
10% reduction	1.41	1.27	1.69	1.51	1.44	1.46
25% reduction	3.42	3.09	4.11	3.68	3.48	3.56
40% reduction	5.31	4.78	6.38	5.71	5.38	5.51
25% increase	-3.70	-3.34	-4.40	-3.97	-3.75	-3.83
California						
10% reduction	1.46	1.66	1.78	1.63	1.44	1.59
25% reduction	3.56	4.05	4.16	3.97	3.50	3.85
40% reduction	5.51	6.28	6.45	6.16	5.42	5.96
25% increase	-3.83	-4.35	-4.45	-4.26	-3.77	-4.13
Nevada						
10% reduction	1.59	1.78	1.65	1.53	1.54	1.62
25% reduction	3.87	4.31	4.02	3.72	3.74	3.93
40% reduction	5.99	6.69	6.23	5.76	5.82	6.10
25% increase	-4.15	-4.61	-4.31	-4.00	-4.05	-4.22
New Mexico						
10% reduction	1.61	1.51	1.41	1.54	1.47	1.51
25% reduction	3.92	3.68	3.46	3.74	3.58	3.68
40% reduction	6.07	5.71	5.35	5.79	5.56	5.70
25% increase	-4.21	-3.96	-3.72	-4.02	-3.86	-3.95
Oklahoma						
10% reduction	1.73	1.54	1.49	1.45	1.35	1.51
25% reduction	4.20	3.74	3.33	3.52	3.29	3.62
40% reduction	6.52	5.82	5.62	5.46	5.09	5.65
25% increase	-4.49	-4.05	-3.91	-3.81	-3.56	-3.96
Texas						
10% reduction	1.27	1.43	1.28	1.32	1.40	1.34
25% reduction	3.06	3.48	3.12	3.20	3.41	3.25
40% reduction	4.73	5.40	4.84	4.97	5.29	5.05
25% increase	-3.31	-3.76	-3.38	-3.47	-3.70	-3.52

Table D.7. Predicted cotton yield adjustments by state, year and ozone assumption for irrigated cotton (Acala SJ-2, 1982)

State and Ozone Assumption	Year 1978	1979	1980	1981	1982	1978-82 Average
Arizona						
10% reduction	3.89	3.22	5.44	4.44	4.00	4.20
25% reduction	8.73	7.19	12.30	10.00	8.97	9.44
40% reduction	12.35	10.14	13.04	14.19	12.69	12.48
25% increase	-11.86	- 9.91	-16.02	-13.38	-12.14	-12.66
California						
10% reduction	4.18	5.30	5.55	5.10	4.05	4.84
25% reduction	9.38	11.98	12.57	11.52	9.09	10.91
40% reduction	13.29	17.05	17.92	16.39	12.87	15.50
25% increase	-12.63	-15.66	-16.34	-15.15	-12.27	-14.41
Nevada						
10% reduction	4.85	5.93	5.20	4.51	4.60	5.02
25% reduction	10.93	13.45	11.78	10.16	10.35	11.42
40% reduction	15.52	19.21	16.76	14.42	14.70	16.12
25% increase	-14.45	-17.31	-15.45	-13.57	-13.79	-14.91
New Mexico						
10% reduction	4.97	4.44	3.95	4.56	4.22	4.43
25% reduction	11.23	9.99	8.87	10.28	9.49	9.97
40% reduction	15.95	14.17	12.55	14.58	13.45	14.14
25% increase	-14.79	-13.35	-12.00	-13.70	-12.76	-13.32

Table D.8. Predicted winter wheat (pooled cultivars) yield adjustments, by state, year and April-May ozone concentrations

State and Ozone Assumption	1978	1979	1980	1978-80 Average
	----------------	percent	----------------------	
Arizona				
10% reduction	N.A.	1.75	1.45	1.60
25% reduction	N.A.	4.01	3.30	3.65
40% reduction	N.A.	5.80	4.77	5.29
25% increase	N.A.	-5.22	-4.33	-4.78
Arkansas				
10% reduction	1.33	2.01	1.50	1.61
25% reduction	3.02	4.59	3.43	3.68
40% reduction	4.37	6.66	4.96	5.33
25% increase	-3.98	-5.94	-4.49	-4.80
California				
10% reduction	N.A.	1.57	1.40	1.48
25% reduction	N.A.	3.59	3.20	3.39
40% reduction	N.A.	5.19	4.62	4.90
25% increase	N.A.	-4.69	-4.20	-4.45
Colorado				
10% reduction	1.72	1.78	1.64	1.71
25% reduction	3.92	4.07	3.74	3.91
40% reduction	5.67	5.89	5.41	5.66
25% increase	5.11	5.29	4.88	5.09
Idaho				
10% reduction	N.A.	1.57	1.65	1.61
25% reduction	N.A.	3.59	3.78	3.68
40% reduction	N.A.	5.19	5.47	5.33
25% increase	N.A.	-4.69	-4.93	-4.81
Illinois				
10% reduction	1.37	.85	1.26	1.16
25% reduction	3.12	1.92	2.87	2.63
40% reduction	4.51	2.77	4.14	3.80
25% increase	-4.10	-2.57	-3.78	-3.48
Indiana				
10% reduction	1.19	.74	.79	.91
25% reduction	2.72	1.69	1.79	2.07
40% reduction	3.92	2.43	2.58	2.97
25% increase	-3.59	-2.25	-2.39	-2.74
Kansas				
10% reduction	1.10	1.31	1.06	1.57
25% reduction	2.51	2.98	2.41	2.63
40% reduction	3.63	4.30	3.48	3.80
25% increase	-3.33	-3.92	-3.20	-3.48

Table D.8. (continued)

State and Ozone Assumption	1978	1979	1980	1978-80 Average
	percent			
Kentucky				
10% reduction	1.14	.98	1.10	1.07
25% reduction	2.60	2.24	2.50	2.45
40% reduction	3.75	3.23	3.60	3.52
25% increase	-3.44	-2.98	-3.30	-3.24
Michigan				
10% reduction	.98	.62	.83	.81
25% reduction	2.23	1.40	1.88	1.84
40% reduction	3.22	2.02	2.71	2.65
25% increase	-2.96	-1.88	-2.50	-2.45
Missouri				
10% reduction	1.06	1.70	1.64	1.47
25% reduction	2.42	3.89	3.76	3.36
40% reduction	3.50	5.63	5.43	4.85
25% increase	-3.21	-5.07	-4.90	-4.39
Montana				
10% reduction	.52	1.24	1.64	1.13
25% reduction	1.19	2.83	3.75	2.59
40% reduction	1.71	4.09	5.42	3.74
25% increase	-1.60	-3.74	-4.89	-3.41
Nebraska				
10% reduction	1.33	1.36	1.28	1.32
25% reduction	3.03	3.41	2.93	3.12
40% reduction	4.38	4.49	4.23	4.37
25% increase	-3.99	-4.09	-3.86	-3.98
New Mexico				
10% reduction	1.68	1.28	1.28	1.41
25% reduction	3.84	2.91	2.92	3.22
40% reduction	5.55	4.20	4.22	4.66
25% increase	-5.00	-3.83	-3.85	-4.23
New York				
10% reduction	1.31	.96	1.09	1.12
25% reduction	2.99	2.19	2.47	2.55
40% reduction	4.32	3.15	3.57	3.68
25% increase	-3.94	-2.91	-3.27	-3.37
North Carolina				
10% reduction	1.58	1.33	1.94	1.62
25% reduction	3.60	3.03	4.44	3.69
40% reduction	5.20	4.38	6.43	5.34
25% increase	-4.70	-3.99	-5.74	-4.81

Table D.8. (continued)

State and Ozone Assumption	1978	1979	1980	1978-80 Average
	----------------	percent	----------------	----------------
Ohio				
10% reduction	1.16	.94	.72	.94
25% reduction	2.64	2.14	1.64	2.14
40% reduction	3.82	3.08	2.36	3.08
25% increase	-3.50	-2.84	-2.20	-2.85
Oklahoma				
10% reduction	1.17	1.36	.74	1.09
25% reduction	2.66	3.10	1.67	2.47
40% reduction	3.84	4.47	2.41	3.57
25% increase	-3.52	-4.07	-2.23	-3.27
Pennsylvania				
10% reduction	1.31	.82	1.13	1.09
25% reduction	2.99	1.87	2.58	2.48
40% reduction	4.33	2.69	3.72	3.58
25% increase	-3.94	-2.49	-3.41	-3.28
South Carolina				
10% reduction	1.80	1.65	2.14	1.86
25% reduction	4.12	3.76	4.90	4.26
40% reduction	5.96	5.44	7.11	6.17
25% increase	-5.35	-4.91	-6.31	-5.52
South Dakota				
10% reduction	.99	.99	1.16	1.05
25% reduction	2.24	2.26	2.63	2.38
40% reduction	3.24	3.26	3.80	3.43
25% increase	-2.98	-3.00	-3.48	-3.15
Tennessee				
10% reduction	1.32	.93	1.45	1.23
25% reduction	3.01	2.10	3.31	2.81
40% reduction	4.34	3.03	4.79	4.05
25% increase	-3.96	-2.80	-4.34	-3.70
Texas				
10% reduction	1.29	1.14	1.14	1.19
25% reduction	2.94	2.60	2.60	2.71
40% reduction	4.25	3.75	3.75	3.97
25% increase	-3.87	-3.44	-3.44	-3.58
Wyoming				
10% reduction	1.58	1.73	1.66	1.66
25% reduction	3.61	3.96	3.79	3.79
40% reduction	5.22	5.73	5.48	5.48
25% increase	-4.72	-5.15	-4.94	-4.94

Table D.9. Predicted spring wheat yield adjustments by state, year and ozone assumption a/

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
Arizona						
10% reduction	.54	.44	.78	.63	.56	.59
25% reduction	1.17	.95	1.68	1.35	1.21	1.27
40% reduction	1.60	1.30	2.31	1.85	1.65	1.74
25% increase	-1.86	-1.51	-2.65	-2.14	-1.91	-2.01
California						
10% reduction	.59	.76	.80	.73	.57	.69
25% reduction	1.26	1.64	1.72	1.57	1.22	1.48
40% reduction	1.73	2,24	2.36	2.15	1.67	2.03
25% increase	-2.00	-2.58	-2.71	-2.48	-1.94	-2.34
Idaho						
10% reduction	N.A.	.75	.55	.62	.63	.64
25% reduction	N.A.	1.62	1.18	1.33	1.35	1.37
40% reduction	N.A.	2.22	1.61	1.82	1.85	1.88
25% increase	N.A.	-2.56	-1.87	-2.10	-2.13	-2.05
Minnesota						
10% reduction	.49	.28	.35	.21	.23	.31
25% reduction	1.05	.61	.76	.45	.49	.67
40% reduction	1.44	.84	1.03	.61	.68	.92
25% increase	-1.67	- .98	-1,20	- .72	- .79	-1,07
Montana						
10% reduction	.23	.69	.52	.56	.56	.51
25% reduction	.50	1.48	1.13	1.20	1.21	1.10
40% reduction	.68	2.03	1.54	1.64	1.66	1.51
25% increase	- .80	-2.34	-1.79	-1.90	-1.92	-1.75
North Dakota						
10% reduction	.30	.27	.32	.30	.24	.29
25% reduction	.64	.59	.70	.65	.51	.62
40% reduction	.87	.80	.96	.89	.69	.84
25% increase	-1.02	- .94	-1.11	-1.04	- .81	- .98
Oregon						
10% reduction	.12	.16	.20	.26	.32	.21
25% reduction	.26	.35	.42	.55	.70	.46
40% reduction	.36	.48	.57	.75	.95	.62
25% increase	- .42	- .56	- .67	- .88	-1.11	- .73
South Dakota						
10% reduction	.44	.34	.43	.30	.22	.35
25% reduction	.94	.73	.92	.66	.47	.74
40% reduction	1.28	1.00	1.26	.90	.65	1.02
25% increase	-1.49	-1.16	-1.46	-1.05	- .76	-1.18

Table D.9. (continued)

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
Washington						
10% reduction	.13	.18	.11	.14	.14	.14
25% reduction	.27	.39	.24	.31	.30	.30
40% reduction	.37	.54	.33	.42	.41	.41
25% increase	- .44	- .63	- .39	- .49	- .49	- .49

[a] Predicted yield adjustment based on Weibull response model of Blueboy II, Coker 47-27, Holly and Oasis cultivars.

Table D.10. Predicted barley yield adjustments by state, year and ozone assumption a/

State and Ozone Assumption	Year					1978-82 Average
	1978	1979	1980	1981	1982	
	(percent yield change)					
Arizona						
10% reduction	.06	.04	.10	.07	.06	.07
25% reduction	.11	.08	.19	.14	.11	.13
40% reduction	.14	.11	.24	.18	.15	.16
25% increase	-.26	-.19	-.44	-.32	-.27	-.30
California						
10% reduction	.07	.10	.10	.09	.06	.08
25% reduction	.29	.17	.20	.18	.12	.16
40% reduction	.16	.23	.25	.22	.15	.20
25% increase	-.29	-.42	-.45	-.40	-.28	-.37
Colorado						
10% reduction	.09	.10	.09	.07	.09	.09
25% reduction	.17	.19	.18	.14	.18	.17
40% reduction	.22	.24	.23	.18	.22	.22
25% increase	-.39	-.43	-.41	-.32	-.40	-.39
Delaware						
10% reduction	.05	.06	.02	.12	.08	.06
25% reduction	.09	.11	.04	.23	.16	.13
40% reduction	.11	.14	.05	.29	.19	.16
25% increase	-.20	-.24	-.09	-.53	-.35	-.28
Idaho						
10% reduction	N.A.	.09	.06	.07	.07	.07
25% reduction	N.A.	.18	.12	.14	.14	.15
40% reduction	N.A.	.23	.14	.17	.18	.18
25% increase	N.A.	-.42	-.26	-.31	-.32	-.33
Illinois						
10% reduction	.09	.06	.07	.04	.06	.06
25% reduction	.17	.11	.13	.08	.11	.12
40% reduction	.21	.14	.16	.10	.14	.15
25% increase	-.38	-.25	-.29	-.18	-.26	-.27
Kansas						
10% reduction	.07	.05	.06	.04	.04	.05
25% reduction	.14	.10	.11	.07	.08	.10
40% reduction	.17	.12	.14	.09	.10	.12
25% increase	-.31	-.22	-.25	-.16	-.17	-.22
Kentucky						
10% reduction	.08	.03	.05	.03	.06	.05
25% reduction	.15	.06	.11	.06	.11	.10
40% reduction	.19	.07	.13	.07	.14	.12
25% increase	-.34	-.13	-.24	-.13	-.26	-.22

Table D.10. (continued)

State and Ozone Assumption	Year					1978-82 Average
	1978	1979	1980	1981	1982	
	(percent yield change)					
Maryland						
10% reduction	.05	.04	.08	.08	.09	.07
25% reduction	.11	.08	.15	.17	.18	.14
40% reduction	.13	.10	.19	.21	.23	.17
25% increase	-.24	-.18	-.34	-.37	-.41	-.31
Michigan						
10% reduction	.03	.02	.03	.03	.03	.03
25% reduction	.05	.04	.05	.05	.06	.05
40% reduction	.07	.05	.06	.07	.08	.06
25% increase	-.12	-.09	-.11	-.12	-.14	-.12
Minnesota						
10% reduction	.05	.02	.03	.01	.02	.03
25% reduction	.10	.04	.06	.03	.03	.05
40% reduction	.12	.06	.08	.03	.04	.07
25% increase	-.22	-.10	-.14	-.06	-.07	-.12
Montana						
10% reduction	.02	.08	.06	.06	.06	.06
25% reduction	.03	.16	.11	.12	.12	.11
40% reduction	.04	.20	.14	.15	.15	.14
25% increase	-.07	-.36	-.24	-.27	-.27	-.24
Nebraska						
10% reduction	.08	.04	.06	.03	.02	.04
25% reduction	.16	.08	.11	.05	.03	.09
40% reduction	.19	.10	.14	.07	.04	.11
25% increase	-.35	-.19	-.25	-.12	-.07	-.19
Nevada						
10% reduction	.08	.11	.09	.07	.08	.09
25% reduction	.16	.22	.18	.14	.15	.17
40% reduction	.20	.28	.23	.18	.19	.22
25% increase	-.37	-.50	-.41	-.33	-.34	-.39
New Jersey						
10% reduction	.04	.05	.12	.09	.10	.08
25% reduction	.08	.09	.23	.17	.19	.15
40% reduction	.10	.12	.28	.22	.24	.19
25% increase	-.18	-.21	-.51	-.39	-.43	-.35
New Mexico						
10% reduction	.09	.07	.06	.08	.07	.07
25% reduction	.17	.14	.12	.15	.13	.14
40% reduction	.21	.18	.15	.18	.16	.18
25% increase	-.38	-.32	-.26	-.33	-.29	-.32

Table D.10. (continued)

State and Ozone Assumption	Year					1978-82 Average
	1978	1979	1980	1981	1982	
	--------------- (percent yield change) ----------------					
New York						
10% reduction	.04	.03	.04	.02	.02	.03
25% reduction	.08	.07	.07	.05	.05	.06
40% reduction	.10	.08	.09	.06	.06	.08
25% increase	-.18	-.15	-.16	-.11	-.10	-.14
North Carolina						
10% reduction	.17	.04	.13	.07	.06	.09
25% reduction	.34	.07	.25	.14	.12	.18
40% reduction	.42	.09	.31	.18	.15	.23
25% increase	-.77	-.16	-.56	-.32	-.27	-.42
North Dakota						
10% reduction	.02	.02	.03	.02	.02	.02
25% reduction	.05	.04	.05	.05	.03	.04
40% reduction	.06	.05	.07	.06	.04	.06
25% increase	-.11	-.09	-.12	-.11	-.08	-.10
Ohio						
10% reduction	.06	.03	.04	.04	.05	.04
25% reduction	.12	.05	.09	.07	.10	.09
40% reduction	.15	.07	.11	.09	.12	.11
25% increase	-.27	-.12	-.20	-.16	-.22	-.19
Oklahoma						
10% reduction	.11	.08	.07	.06	.05	.07
25% reduction	.21	.15	.14	.12	.10	.14
40% reduction	.26	.19	.17	.16	.13	.18
25% increase	-.47	-.34	-.31	-.28	-.23	-.32
Oregon						
10% reduction	.01	.01	.01	.02	.03	.02
25% reduction	.01	.02	.03	.04	.05	.03
40% reduction	.02	.02	.03	.05	.07	.04
25% reduction	-.03	-.04	-.06	-.09	-.12	-.07
Pennsylvania						
10% reduction	.05	.03	.06	.03	.04	.04
25% reduction	.09	.05	.11	.05	.07	.08
40% reduction	.12	.07	.14	.07	.09	.10
25% increase	-.21	-.12	-.25	-.12	-.16	-.17
South Carolina						
10% reduction	.24	.06	.12	.08	.07	.12
25% reduction	.47	.12	.23	.16	.15	.23
40% reduction	.59	.16	.29	.20	.18	.28
25% increase	-1.07	-.28	-.53	-.35	-.33	-.51

Table D.10.(continued)

State and Ozone Assumption	Year					1978-82 Average
	1978	1979	1980	1981	1982	
	---------------- (percent yield change) ----------------					
South Dakota						
10% reduction	.04	.03	.04	.02	.02	.03
25% reduction	.08	.06	.08	.05	.03	.06
40% reduction	.10	.07	.10	.06	.04	.07
25% increase	-.19	-.13	-.18	-.11	-.07	-.13
Tennessee						
10% reduction	.09	.02	.06	.05	.07	.06
25% reduction	.17	.04	.13	.09	.14	.11
40% reduction	.22	.04	.16	.11	.18	.14
25% increase	-.39	-.09	-.28	-.20	-.32	-.26
Texas						
10% reduction	.04	.06	.04	.05	.06	.05
25% reduction	.08	.12	.09	.09	.11	.10
40% reduction	.10	.15	.11	.12	.14	.12
25% increase	-.19	-.27	-.20	-.21	-.26	-.23
Utah						
10% reduction	.08	.08	.11	.09	.11	.09
25% reduction	.16	.15	.22	.17	.21	.18
40% reduction	.20	.18	.27	.21	.26	.22
25% increase	-.35	-.33	-.49	-.38	-.47	-.40
Virginia						
10% reduction	.11	.04	.13	.07	.08	.09
25% reduction	.22	.07	.25	.14	.16	.17
40% reduction	.27	.09	.31	.18	.20	.21
25% increase	-.49	-.16	-.57	-.33	-.36	-.38
Washington						
10% reduction	.01	.01	.01	.01	.01	.01
25% reduction	.01	.02	.01	.02	.02	.02
40% reduction	.02	.03	.01	.02	.02	.02
25% increase	-.03	-.05	-.03	-.04	-.04	-.04
West Virginia						
10% reduction	.04	.03	.05	.03	.04	.04
25% reduction	.08	.05	.10	.06	.07	.07
40% reduction	.10	.06	.12	.07	.09	.09
25% increase	-.18	-.12	-.22	-.13	-.17	-.16
Wisconsin						
10% reduction	.06	.05	.04	.03	.03	.04
25% reduction	.12	.09	.07	.05	.06	.08
40% reduction	.15	.12	.09	.07	.07	.10
25% increase	-.26	-.21	-.15	-.12	-.13	-.18

Table D.10. (continued)

State and Ozone Assumption	Year 1978	1979	1980	1981	1982	1978-82 Average
	(percent yield change)					
Wyoming						
10% reduction	.06	.09	.07	.08	.08	.08
25% reduction	.12	.18	.14	.15	.16	.15
40% reduction	.15	.23	.17	.19	.21	.19
25% increase	-.28	-.41	-.31	-.35	-.37	-.34

[a] Predicted yield changes based on Weibull response model for Poco cultivar.

Table D.11. Predicted sorghum yield adjustments by year, state and ozone assumption a/

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
Alabama						
10% reduction	.41	.26	.35	.36	.41	.36
25% reduction	.94	.60	.80	.81	.94	.82
40% reduction	1.35	.86	1.15	1.17	1.35	1.18
25% increase	-1.26	- .81	-1.08	-1.09	-1.26	-1.10
Arizona						
10% reduction	.33	.28	.43	.37	.34	.35
25% reduction	.75	.64	.99	.84	.77	.80
40% reduction	1.08	.92	1.42	1.20	1.10	1.14
25% increase	-1.01	- .86	-1.32	-1.12	-1.03	-1.07
California						
10% reduction	.35	.43	.44	.41	.34	.39
25% reduction	.79	.97	1.00	.94	.77	.89
40% reduction	1.14	1.39	1.45	1.35	1.11	1.29
25% increase	-1.07	-1.30	-1.35	-1.26	-1.04	-1.20
Colorado						
10% reduction	.41	.43	.42	.37	.41	.41
25% reduction	.93	.97	.96	.84	.94	.93
40% reduction	1.34	1.49	1.38	1.21	1.35	1.34
25% increase	-1.25	-1.31	-1.28	-1.31	-1.26	-1.28
Georgia						
10% reduction	.49	.30	.35	.33	.33	.36
25% reduction	1.12	.67	.79	.76	.75	.82
40% reduction	1.61	.97	1.14	1.09	1.08	1.18
25% increase	-1.50	- .90	-1.07	-1.02	-1.01	-1.10
Illinois						
10% reduction	.40	.33	.35	.27	.33	.34
25% reduction	.92	.74	.80	.61	.75	.76
40% reduction	1.32	1.06	1.15	.88	1.07	1.10
25% increase	-1.23	.99	-1.07	- .83	-1.00	-1.02
Indiana						
10% reduction	.38	.24	.35	.32	.36	.33
25% reduction	.86	.56	.79	.73	.81	.75
40% reduction	1.24	.80	1.14	1.05	1.17	1.08
25% increase	-1.16	- .75	-1.06	- .98	-1.09	-1.01
Iowa						
10% reduction	.36	.26	.28	.16	.19	.25
25% reduction	.81	.58	.63	.36	.42	.56
40% reduction	1.17	.84	.90	.52	.61	.81
25% increase	-1.09	- .78	- .34	- .49	- .57	- .75

Table D.11. (continued)

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
Kansas						
10% reduction	.36	.30	.33	.26	.27	.30
25% reduction	.82	.68	.74	.59	.61	.69
40% reduction	1.18	.98	1.07	.85	.88	.99
25% increase	-1.10	- .92	-1.00	- .80	- .82	- .93
Kentucky						
10% reduction	.38	.23	.32	.24	.33	.30
25% reduction	.87	.53	.72	.53	.75	.68
40% reduction	1.25	.77	1.04	.77	1.08	.98
25% increase	-1.17	- .72	- .97	- .72	-1.01	- .92
Louisiana						
10% reduction	.29	.19	.28	.27	.24	.25
25% reduction	.67	.42	.63	.62	.55	.58
40% reduction	.96	.60	.91	.89	.80	.83
25% increase	- .90	- .57	- .85	- .84	- .75	- .78
Mississippi						
10% reduction	.45	.25	.39	.36	.31	.35
25% reduction	1.02	.57	.89	.81	.70	.80
40% reduction	1.47	.83	1.28	1.16	1.01	1.15
25% increase	-1.37	- .78	-1.19	-1.09	- .95	-1.08
Missouri						
10% reduction	.45	.38	.39	.22	.25	.34
25% reduction	1.03	.86	.89	.49	.57	.77
40% reduction	1.48	1.24	1.28	.71	.82	1.11
25% increase	-1.38	-1.15	-1.19	- .66	- .76	-1.03
Nebraska						
10% reduction	.39	.28	.32	.22	.17	.28
25% reduction	.88	.63	.73	.50	.38	.62
40% reduction	1.27	.91	1.06	.72	.54	.90
25% increase	-1.18	- .85	- .99	- .68	- .51	- .84
New Mexico						
10% reduction	.40	.37	.33	.38	.35	.37
25% reduction	.92	.84	.76	.85	.80	.83
40% reduction	1.32	1.20	1.09	1.23	1.15	1.20
25% increase	-1.23	-1.12	-1.02	-1.15	-1.08	-1.12
North Carolina						
10% reduction	.58	.26	.49	.37	.34	.41
25% reduction	1.32	.58	1.12	.84	.77	.93
40% reduction	1.90	.84	1.61	1.20	1.10	1.33
25% increase	-1.76	- .79	-1.50	-1.12	-1.03	-1.24

Table D.11. (continued)

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
Oklahoma						
10% reduction	.45	.38	.36	.35	.30	.37
25% reduction	1.02	.86	.82	.78	.69	.83
40% reduction	1.47	1.24	1.18	1.13	.99	1.20
25% increase	-1.37	-1.16	-1.10	-1.05	- .93	-1.12
Pennsylvania						
10% reduction	.30	.22	.32	.22	.26	.26
25% reduction	.68	.51	.73	.50	.59	.60
40% reduction	.98	.73	1.05	.73	.84	.87
25% increase	- .91	- .69	- .98	- .68	- .79	- .81
South Carolina						
10% reduction	.69	.34	.48	.39	.38	.46
25% reduction	1.57	.78	1.09	.88	.85	1.03
40% reduction	2.26	1.13	1.57	1.27	1.23	1.49
25% increase	-2.09	-1.05	-1.46	-1.19	-1.14	-1.39
South Dakota						
10% reduction	.28	.23	.27	.21	.17	.23
25% reduction	.63	.52	.62	.48	.37	.52
40% reduction	.91	.75	.90	.69	.54	.76
25% increase	- .85	- .70	- .84	- .65	- .51	- .71
Tennessee						
10% reduction	.41	.19	.35	.29	.37	.32
25% reduction	.93	.42	.79	.66	.84	.73
40% reduction	1.34	.61	1.13	.96	1.21	1.05
25% increase	-1.25	- .57	-1.06	- .89	-1.13	- .98
Texas						
10% reduction	.28	.34	.29	.30	.33	.31
25% reduction	.63	.77	.65	.68	.75	.70
40% reduction	.91	1.11	.94	.98	1.08	1.00
25% increase	- .85	-1.03	- .88	- .91	-1.01	- .94
Virginia						
10% reduction	.46	.26	.50	.37	.39	.40
25% reduction	1.04	.58	1.13	.85	.89	.90
40% reduction	1.50	.84	1.62	1.22	1.28	1.29
25% increase	-1.40	- .78	-1.51	-1.14	-1.20	-1.21

[a] Predicted yield changes based on Weibull response model for Dekalb-28 cultivar.

Table D.12. Predicted soybean yield adjustments using pooled regional response functions

State	Ozone Assumption			
	10% Reduction	25% Reduction	40% Reduction	25% Increase
	percent			
Alabama[a/]	2.7	6.4	9.9	7.0
Arkansas[a/]	2.9	7.5	11.6	8.0
Delaware[b/]	1.7	4.2	6.4	4.6
Florida[a/]	1.7	4.1	6.2	4.5
Georgia[a/]	2.6	6.4	9.9	6.9
Illinois[b/]	2.7	6.4	10.0	6.9
Indiana[b/]	2.6	6.4	9.8	6.9
Iowa[b/]	2.2	5.4	8.3	5.9
Kansas[b/]	2.5	6.1	9.4	6.6
Kentucky[b/]	2.5	6.0	9.2	6.5
Louisiana[a/]	2.2	5.4	8.3	5.9
Maryland[b/]	2.8	6.8	10.5	7.3
Michigan[b/]	1.9	4.5	6.9	4.9
Minnesota[b/]	2.0	4.8	7.4	5.3
Mississippi[a/]	2.9	7.0	10.7	7.5
Missouri[b/]	2.9	6.9	10.7	7.5
Nebraska[b/]	2.5	6.0	9.3	6.5
New Jersey[b/]	3.3	8.0	12.3	8.5
New York[b/]	2.1	5.1	7.9	5.6
North Carolina[a/]	3.4	8.2	12.8	8.7
North Dakota[b/]	1.9	4.6	7.1	5.1
Ohio[b/]	2.3	5.5	8.5	6.0
Oklahoma[b/]	2.7	6.5	10.1	7.1
Pennsylvania[b/]	2.5	6.0	9.3	6.5
South Carolina[a/]	3.3	8.1	12.5	8.6
South Dakota[b/]	2.2	5.4	8.3	5.9
Tennessee[a/]	2.6	6.4	9.8	6.9
Texas[a/]	2.3	5.6	8.5	6.0
Virginia[a/]	3.4	8.3	2.8	8.8
Wisconsin[b/]	2.1	5.1	7.8	5.5

(continued)

[a] Includes Southeast and Southern cultivars of soybeans (Davis, Essex and Forrest).

[b] Includes Corn Belt and Lake states cultivars (Amsoy, Corsoy, Williams and Hodgson).

Table D.13. Predicted soybean (Davis' 81 cv.) yield adjustments by state, year and ozone assumption

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
Alabama						
10% reduction	3.98	3.32	3.73	3.75	3.97	3.75
25% reduction	10.36	8.61	9.70	9.76	10.35	9.76
40% reduction	17.31	14.32	16.18	16.28	17.30	16.28
25% increase	- 9.01	- 7.69	- 8.57	- 8.62	- 9.09	- 8.60
Arkansas						
10% reduction	4.40	3.95	4.05	3.78	3.63	3.96
25% reduction	11.51	10.29	10.54	9.82	9.43	10.32
40% reduction	19.30	17.20	17.64	16.39	15.72	17.25
25% increase	-10.01	- 9.05	- 9.25	- 8.67	- 8.36	- 9.07
Delware						
10% reduction	3.45	3.59	2.95	4.22	3.87	3.62
25% reduction	8.95	9.33	7.62	11.02	10.08	9.39
40% reduction	14.90	15.54	12.63	18.45	16.84	15.67
25% increase	- 7.96	- 8.27	- 6.86	- 9.63	- 8.88	- 8.32
Florida						
10% reduction	3.41	2.85	2.90	3.41	3.15	3.14
25% reduction	8.85	7.37	7.49	8.86	8.16	8.15
40% reduction	14.73	12.20	12.41	14.74	13.56	13.53
25% increase	- 7.88	- 6.65	- 6.75	- 7.89	- 7.32	- 7.30
Georgia						
10% reduction	4.27	3.48	3.72	3.65	3.64	3.75
25% reduction	11.14	9.02	9.67	9.49	9.45	9.75
40% reduction	18.67	15.02	16.13	15.82	15.75	16.28
25% increase	- 9.72	- 8.02	- 8.55	- 8.40	- 8.37	- 8.61
Illinois						
10% reduction	3.94	3.61	3.73	3.36	3.63	3.65
25% reduction	10.25	9.38	9.69	8.70	9.42	9.48
40% reduction	17.13	15.64	16.16	14.47	15.71	15.82
25% increase	- 9.02	- 8.32	- 8.56	- 7.76	- 8.35	- 8.40
Indiana						
10% reduction	3.84	3.23	3.71	3.60	3.76	3.63
25% reduction	10.00	8.35	9.65	9.35	9.77	9.42
40% reduction	16.70	13.88	16.10	15.57	16.30	15.71
25% increase	- 8.82	- 7.47	- 8.53	- 8.29	- 8.63	- 8.35
Iowa						
10% reduction	3.75	3.29	3.39	2.68	2.90	3.20
25% reduction	9.75	8.52	8.78	6.92	7.49	8.29
40% reduction	16.27	14.16	14.61	11.45	12.41	13.78
25% increase	- 8.61	- 7.61	- 7.82	- 6.27	- 6.75	- 7.41

Table D.13. (continued)

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
Kansas						
10% reduction	3.77	3.50	3.62	3.30	3.35	3.51
25% reduction	9.80	9.09	9.42	8.57	8.69	9.11
40% reduction	16.36	15.14	15.69	14.24	14.45	15.18
25% increase	- 8.66	- 8.08	- 8.34	- 7.65	- 7.75	- 8.10
Kentucky						
10% reduction	3.85	3.17	3.58	3.17	3.64	3.48
25% reduction	10.03	8.21	9.30	8.22	9.45	9.04
40% reduction	16.75	13.63	15.50	13.65	15.76	15.06
25% increase	- 8.84	- 7.35	- 8.25	- 7.36	- 8.37	- 8.03
Louisiana						
10% reduction	3.47	2.88	3.39	3.37	3.22	3.27
25% reduction	9.00	7.45	8.80	8.75	8.34	8.47
40% reduction	14.98	12.35	14.64	14.55	13.85	14.07
25% increase	- 8.00	- 6.72	- 7.84	- 7.80	- 7.46	- 7.56
Maryland						
10% reduction	3.58	3.36	3.85	3.92	3.99	3.74
25% reduction	9.31	8.72	10.03	10.22	10.41	9.74
40% reduction	15.51	14.51	16.75	17.07	17.40	16.25
25% increase	- 8.26	- 7.78	- 8.84	- 8.99	- 9.14	- 8.60
Michigan						
10% reduction	3.09	2.92	3.06	3.09	3.19	3.07
25% reduction	8.01	7.54	7.91	7.98	8.26	7.94
40% reduction	13.29	12.50	13.13	13.25	13.73	13.18
25% increase	- 7.19	- 6.80	- 7.11	- 7.17	- 7.40	- 7.13
Minnesota						
10% reduction	3.52	3.27	3.18	2.71	2.80	3.10
25% reduction	9.13	8.47	8.24	7.00	7.22	8.01
40% reduction	15.21	14.09	13.68	11.59	11.95	13.30
25% increase	- 8.11	- 7.57	- 7.38	- 6.34	- 6.52	- 7.18
Mississippi						
10% reduction	4.11	3.27	3.89	3.75	3.55	3.71
25% reduction	10.71	8.47	10.13	9.74	9.21	9.65
40% reduction	17.92	14.09	16.92	16.25	15.34	16.10
25% increase	- 9.38	- 7.57	- 8.92	- 8.61	- 8.18	- 8.53
Missouri						
10% reduction	4.12	3.84	3.89	3.08	3.25	3.64
25% reduction	10.75	9.99	10.12	7.96	8.42	9.45
40% reduction	17.98	16.68	16.90	13.21	14.00	15.75
25% increase	- 9.41	- 8.81	- 8.91	- 7.14	- 7.53	- 8.36

Table D.13. (continued)

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
Nebraska						
10% reduction	3.88	3.40	3.60	3.10	2.76	3.35
25% reduction	10.09	8.82	9.36	8.02	7.13	8.68
40% reduction	16.85	14.67	15.60	13.31	11.80	14.45
25% increase	- 8.88	- 7.85	- 8.30	- 7.19	- 6.45	- 7.73
New Jersey						
10% reduction	3.38	3.49	4.19	3.96	4.03	3.81
25% reduction	8.78	9.06	10.93	10.32	10.51	9.92
40% reduction	14.60	15.09	18.29	17.26	17.58	16.56
25% increase	- 7.82	- 8.06	- 9.55	- 9.07	- 9.22	- 8.74
New York						
10% reduction	3.39	3.24	3.30	3.03	3.00	3.19
25% reduction	8.78	8.39	8.55	7.83	7.76	8.26
40% reduction	14.61	13.94	14.22	13.00	12.87	13.73
25% increase	- 7.83	- 7.50	- 7.64	- 7.04	- 6.98	- 7.40
North Carolina						
10% reduction	4.56	3.29	4.27	3.80	3.67	3.92
25% reduction	11.92	8.53	11.14	9.88	9.53	10.20
40% reduction	20.02	14.19	18.67	16.49	15.90	17.05
25% increase	-10.33	- 7.62	- 9.72	- 8.72	- 8.44	- 8.97
North Dakota						
10% reduction	3.02	2.95	3.11	3.04	2.82	2.99
25% reduction	7.81	7.62	8.04	7.86	7.27	7.72
40% reduction	12.95	12.63	13.34	13.03	12.05	12.80
25% increase	- 7.02	- 6.86	- 7.21	- 7.06	- 6.57	- 6.94
Ohio						
10% reduction	3.66	3.12	3.43	3.31	3.51	3.41
25% reduction	9.51	8.08	8.90	8.58	9.11	8.84
40% reduction	15.86	13.41	14.82	14.26	15.18	14.71
25% increase	- 8.42	- 7.25	- 7.93	- 7.66	- 8.10	- 7.87
Oklahoma						
10% reduction	4.11	3.84	3.76	3.70	3.55	3.79
25% reduction	10.71	9.99	9.79	9.62	9.21	9.86
40% reduction	17.93	16.68	16.33	16.04	15.35	16.47
25% increase	- 9.38	- 8.81	- 8.64	- 8.51	- 8.18	- 8.70
Pennsylvania						
10% reduction	3.50	3.11	3.60	3.11	3.30	3.32
25% reduction	9.07	8.06	9.35	8.04	8.54	8.61
40% reduction	15.11	13.38	15.58	13.34	14.20	14.32
25% increase	- 8.06	- 7.23	- 8.29	- 7.21	- 7.63	- 7.68

Table D.15. (continued)

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
South Carolina						
10% reduction	4.88	3.70	4.22	3.88	3.83	4.10
25% reduction	12.80	9.61	11.00	10.10	9.95	10.69
40% reduction	21.55	16.03	18.43	16.87	16.62	17.90
25% increase	-11.01	- 8.50	- 9.61	- 8.89	- 8.78	- 9.36
South Dakota						
10% reduction	3.40	3.14	3.38	3.05	2.76	3.15
25% reduction	8.81	8.14	8.76	7.88	7.12	8.14
40% reduction	14.66	13.52	14.57	13.08	11.78	13.52
25% increase	- 7.85	- 7.30	- 7.81	- 7.08	- 6.44	- 7.30
Tennessee						
10% reduction	3.97	2.89	3.71	3.46	3.81	3.57
25% reduction	10.33	7.48	9.64	8.99	9.91	9.27
40% reduction	17.26	12.39	16.08	14.97	16.55	15.45
25% increase	- 9.08	- 6.74	- 8.52	- 8.00	- 8.75	- 8.22
Texas						
10% reduction	3.39	3.67	3.44	3.49	3.63	3.52
25% reduction	8.80	9.55	8.92	9.07	9.43	9.15
40% reduction	14.65	15.92	14.85	15.10	15.73	15.25
25% increase	- 7.84	- 8.45	- 7.94	- 8.06	- 8.36	- 8.13
Virginia						
10% reduction	4.15	3.29	4.28	3.81	3.90	3.89
25% reduction	10.81	8.51	11.17	9.92	10.14	10.11
40% reduction	18.10	14.15	18.71	16.56	16.94	16.89
25% increase	- 9.46	- 7.61	- 9.74	- 8.75	- 8.93	- 8.90
Wisconsin						
10% reduction	3.65	3.49	3.27	3.10	3.13	3.33
25% reduction	9.48	9.06	8.47	8.03	8.10	8.63
40% reduction	15.80	15.09	14.07	13.34	13.45	14.35
25% increase	- 8.39	- 8.05	- 7.57	- 7.21	- 7.27	- 7.70

Table D.14. Predicted corn (Pioneer, cv.) yield adjustments by state, year and ozone assumption

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
Alabama						
10% reduction	.87	.46	.70	.71	.87	.72
25% reduction	1.85	.99	1.48	1.51	1.85	1.54
40% reduction	2.51	1.33	2.00	2.04	2.50	2.08
25% increase	-3.05	-1.64	-2.45	-2.50	-3.04	-2.54
Arizona						
10% reduction	.64	.51	.93	.74	.66	.70
25% reduction	1.35	1.08	1.99	1.58	1.39	1.48
40% reduction	1.83	1.46	2.69	2.13	1.88	2.00
25% increase	-2.24	-1.80	-3.27	-2.60	-2.31	-2.44
Arkansas						
10% reduction	1.24	.85	.92	.73	.63	.87
25% reduction	2.65	1.82	1.97	1.55	1.35	1.87
40% reduction	3.59	2.45	2.66	2.09	1.82	2.52
25% increase	-4.32	-2.99	-3.24	-2.55	-2.23	-3.07
California						
10% reduction	.69	.91	.96	.87	.67	.82
25% reduction	1.47	1.93	2.04	1.85	1.42	1.74
40% reduction	1.98	2.61	2.76	2.50	1.91	2.35
25% increase	-2.42	-3.17	-3.35	-3.04	-2.34	-2.86
Colorado						
10% reduction	.86	.92	.89	.75	.87	.86
25% reduction	1.84	1.95	1.91	1.60	1.85	1.83
40% reduction	2.49	2.64	2.58	2.16	2.50	2.48
25% increase	-3.03	-3.21	-3.13	-2.63	-3.04	-3.01
Connecticut						
10% reduction	.63	.82	1.40	.90	.92	.93
25% reduction	1.34	1.74	2.99	1.91	1.95	1.99
40% reduction	1.81	2.36	4.05	2.59	2.64	2.69
25% increase	-2.22	-2.87	-4.85	-3.15	-3.21	-3.26
Delaware						
10% reduction	.53	.61	.31	.51	.79	.55
25% reduction	1.13	1.30	.65	1.08	1.69	1.17
40% reduction	1.52	1.75	.87	1.46	2.28	1.58
25% increase	-1.87	-2.15	-1.08	-1.80	-2.79	-1.94
Florida						
10% reduction	.51	.27	.29	.51	.39	.39
25% reduction	1.08	.58	.61	1.09	.82	.84
40% reduction	1.46	.78	.83	1.47	1.11	1.13
25% increase	-1.80	- .97	-1.02	-1.80	-1.37	-1.39

Table D.14. (continued)

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
Georgia						
10% reduction	1.11	.54	.69	.65	.64	.73
25% reduction	2.38	1.16	1.47	1.38	1.36	1.55
40% reduction	3.22	1.56	1.98	1.86	1.83	2.09
25% increase	-3.88	-1.92	-2.42	-2.28	-2.24	-2.55
Idaho						
10% reduction	N.A.	.90	.64	.73	.74	.75
25% reduction	N.A.	1.91	1.36	1.54	1.57	1.60
40% reduction	N.A.	2.59	1.84	2.09	2.12	2.15
25% increase	N.A.	-3.15	-2.25	-2.55	-2.60	-2.11
Illinois						
10% reduction	.77	.62	.69	.48	.63	.64
25% reduction	1.65	1.32	1.48	1.02	1.34	1.36
40% reduction	2.22	1.79	1.99	1.38	1.81	1.83
25% increase	-2.71	-2.19	-2.44	-1.70	-2.23	-2.25
Indiana						
10% reduction	.77	.42	.68	.61	.71	.64
25% reduction	1.65	.89	1.46	1.31	1.52	1.37
40% reduction	2.22	1.20	1.97	1.76	2.05	1.84
25% increase	-2.71	-1.48	-2.41	-2.16	-2.51	-2.25
Iowa						
10% reduction	.71	.45	.50	.22	.29	.43
25% reduction	1.51	.95	1.05	.47	.61	.92
40% reduction	2.04	1.28	1.42	.63	.83	1.24
25% increase	-2.49	-1.58	-1.75	- .78	-1.02	-1.52
Kansas						
10% reduction	.72	.56	.63	.46	.48	.57
25% reduction	1.54	1.19	1.34	.97	1.02	1.21
40% reduction	2.08	1.60	1.81	1.31	1.37	1.63
25% increase	-2.54	-1.97	-2.22	-1.61	-1.69	-2.01
Kentucky						
10% reduction	.78	.39	.60	.40	.64	.56
25% reduction	1.66	.84	1.29	.84	1.36	1.20
40% reduction	2.24	1.13	1.74	1.14	1.83	1.62
25% increase	-2.74	-1.40	-2.13	-1.40	-2.25	-1.98
Louisiana						
10% reduction	.54	.28	.50	.49	.42	.45
25% reduction	1.15	.60	1.06	1.04	.88	.95
40% reduction	1.55	.81	1.44	1.41	1.19	1.28
25% increase	-1.90	-1.01	-1.77	-1.73	-1.47	-1.58

Table D.14. (continued)

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
Maine						
10% reduction	.52	.35	.28	.20	.29	.33
25% reduction	1.11	.75	.59	.42	.62	.70
40% reduction	1.50	1.01	.80	.57	.84	.94
25% increase	1.85	1.24	- .99	- .71	-1.04	-1.17
Maryland						
10% reduction	.61	.49	.78	.83	.88	.72
25% reduction	1.29	1.03	1.66	1.77	1.88	1.53
40% reduction	1.74	1.39	2.24	2.39	2.55	2.06
25% increase	-2.14	-1.72	-2.74	-2.91	-3.10	-2.52
Massachusetts						
10% reduction	.46	.58	.69	.61	.58	.58
25% reduction	.99	1.22	1.47	1.29	1.23	1.24
40% reduction	1.33	1.65	1.98	1.74	1.66	1.67
25% increase	-1.64	-2.03	-2.43	-2.14	-2.04	-2.06
Michigan						
10% reduction	.36	.30	.35	.36	.40	.35
25% reduction	.77	.63	.74	.76	.86	.75
40% reduction	1.04	.84	1.00	1.03	1.16	1.01
25% increase	-1.28	-1.05	-1.23	-1.27	-1.43	-1.25
Minnesota						
10% reduction	.57	.32	.40	.23	.25	.35
25% reduction	1.21	.68	.85	.49	.54	.75
40% reduction	1.63	.91	1.14	.65	.73	1.01
25% increase	-2.00	-1.13	-1.41	- .81	- .90	-1.25
Mississippi						
10% reduction	.97	.44	.81	.71	.58	.70
25% reduction	2.08	.93	1.72	1.50	1.24	1.49
40% reduction	2.81	1.26	2.32	2.03	1.68	2.02
25% increase	-3.41	-1.56	-2.83	-2.49	-2.06	-2.47
Missouri						
10% reduction	.99	.77	.80	.35	.43	.67
25% reduction	2.10	1.64	1.71	.75	.92	1.42
40% reduction	2.84	2.21	2.31	1.02	1.24	1.92
25% increase	-3.45	-2.70	-2.82	-1.26	-1.53	-2.35
Montana						
10% reduction	.26	.82	.61	.65	.66	.60
25% reduction	.54	1.74	1.30	1.39	1.40	1.27
40% reduction	.73	2.35	1.75	1.88	1.90	1.72
25% increase	- .91	-2.86	-2.15	-2.30	-2.32	-2.11

Table D.14. (continued)

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
Nebraska						
10% reduction	.80	.50	.62	.36	.24	.50
25% reduction	1.69	1.07	1.31	.77	.52	1.07
40% reduction	2.29	1.44	1.77	1.04	.70	1.45
25% increase	-2.79	-1.78	-2.17	-1.29	- .86	-1.78
Nevada						
10% reduction	.82	1.03	.89	.75	.77	.85
25% reduction	1.74	2.20	1.90	1.60	1.64	1.82
40% reduction	2.35	2.97	2.56	2.16	2.22	2.45
25% increase	-2.87	-3.60	-3.12	-2.64	-2.71	-2.99
New Hampshire						
10% reduction	.50	.45	.51	.27	.35	.42
25% reduction	1.07	.95	1.09	.57	.74	.88
40% reduction	1.44	1.29	1.47	.77	.99	1.19
25% increase	-1.77	-1.59	-1.81	- .96	-1.23	-1.37
New Jersey						
10% reduction	.50	.55	1.04	.86	.92	.77
25% reduction	1.05	1.77	2.22	1.83	1.95	1.76
40% reduction	1.42	1.59	3.01	2.48	2.64	2.23
25% increase	-1.75	-1.95	-3.64	-3.02	-3.20	-2.71
New Mexico						
10% reduction	.84	.74	.65	.76	.70	.74
25% reduction	1.80	1.57	1.38	1.63	1.49	1.57
40% reduction	2.43	2.13	1.86	2.20	2.01	2.13
25% increase	-2.96	-2.60	-2.28	-2.68	-2.46	-2.60
New York						
10% reduction	.50	.42	.45	.34	.33	.41
25% reduction	1.06	.90	.96	.71	.69	.86
40% reduction	1.43	1.22	1.30	.96	.93	1.17
25% increase	-1.76	-1.50	-1.60	-1.19	-1.15	-1.44
North Carolina						
10% reduction	1.40	.45	1.11	.74	.66	.87
25% reduction	2.99	.96	2.38	1.58	1.40	1.86
40% reduction	4.05	1.29	3.22	2.13	1.89	2.52
25% increase	-4.85	-1.59	-3.88	-2.61	-2.31	-3.05
North Dakota						
10% reduction	.33	.31	.37	.34	.26	.32
25% reduction	.71	.65	.78	.72	.55	.68
40% reduction	.95	.87	1.05	.97	.75	.92
25% increase	-1.18	-1.08	-1.30	-1.20	- .93	-1.14

Table D.14. (continued)

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
Ohio						
10% reduction	.65	.37	.52	.46	.56	.51
25% reduction	1.39	.79	1.11	.97	1.20	1.09
40% reduction	1.87	1.07	1.49	1.31	1.62	1.47
25% increase	-2.29	-1.32	-1.84	-1.62	-1.99	-1.81
Oklahoma						
10% reduction	.13	.77	.72	.68	.58	.58
25% reduction	.28	1.64	1.53	1.44	1.24	1.23
40% reduction	.37	2.22	2.06	1.94	1.68	1.65
25% increase	- .46	-2.71	-2.52	-2.38	-2.06	-2.03
Oregon						
10% reduction	.12	.18	.21	.28	.37	.23
25% reduction	.28	.37	.45	.60	.78	.50
40% reduction	.37	.50	.61	.82	1.05	.67
25% increase	- .46	- .63	- .76	-1.01	-1.30	- .83
Pennsylvania						
10% reduction	.55	.37	.61	.37	.45	.47
25% reduction	1.18	.79	1.31	.78	.96	1.00
40% reduction	1.59	1.06	1.76	1.05	1.30	1.35
25% increase	-1.	-1.31	-2.16	-1.30	-1.60	-1.67
Rhode Island						
10% reduction	.47	.70	1.03	.94	.88	.80
25% reduction	1.00	1.48	2.20	1.99	1.88	1.71
40% reduction	1.34	2.01	2.98	2.69	2.54	2.31
25% increase	-1.66	-2.45	-3.60	-3.27	-3.09	-2.81
South Carolina						
10% reduction	1.78	.67	1.07	.80	.76	1.02
25% reduction	3.81	1.44	2.28	1.70	1.62	2.17
40% reduction	5.71	1.94	3.08	2.30	2.19	3.04
25% increase	-6.11	-2.37	-3.72	-2.80	-2.67	-3.53
South Dakota						
10% reduction	.50	.38	.49	.34	.24	.39
25% reduction	1.07	.81	1.05	.73	.51	.83
40% reduction	1.44	1.10	1.41	.98	.69	1.12
25% increase	-1.77	-1.36	-1.74	-1.22	- .86	-1.39
Tennessee						
10% reduction	.86	.29	.68	.54	.75	.62
25% reduction	1.84	.61	1.45	1.14	1.60	1.33
40% reduction	2.48	.82	1.96	1.54	2.16	1.79
25% increase	-3.02	-1.02	-2.40	-1.90	-2.64	-2.20

Table D.14. (continued)

State and Ozone Assumption	1978	1979	1980	1981	1982	1978-82 Average
Texas						
10% reduction	.50	.66	.52	.55	.63	.57
25% reduction	1.06	1.40	1.11	1.18	1.35	1.22
40% reduction	1.44	1.90	1.50	1.59	1.82	1.65
25% increase	-1.77	-2.32	-1.85	-1.96	-2.23	-2.03
Utah						
10% reduction	.80	.76	1.01	.84	.98	.87
25% reduction	1.70	1.63	2.15	1.79	2.08	1.87
40% reduction	2.29	2.20	2.91	2.42	2.82	2.53
25% increase	-2.79	-2.68	-3.53	-2.94	-3.42	-3.07
Vermont						
10% reduction	.53	.52	.53	.29	.34	.44
25% reduction	1.13	1.11	1.14	.61	.72	.94
40% reduction	1.53	1.50	1.54	.83	.98	1.28
25% increase	-1.88	-1.85	-1.89	-1.03	-1.21	-1.57
Virginia						
10% reduction	1.01	.45	1.12	.75	.81	.83
25% reduction	2.15	.95	2.40	1.60	1.73	1.77
40% reduction	2.90	1.28	3.24	2.16	2.33	2.38
25% increase	-3.52	-1.58	-3.91	-2.64	-2.84	-2.90
Washington						
10% reduction	.13	.20	.12	.15	.15	.15
25% reduction	.29	.42	.25	.32	.32	.32
40% reduction	.39	.57	.34	.44	.43	.43
25% increase	- .48	- .71	- .42	- .54	- .54	- .54
West Virginia						
10% reduction	.48	.36	.57	.39	.46	.45
25% reduction	1.03	.76	1.22	.83	.98	.96
40% reduction	1.39	1.03	1.65	1.13	1.32	1.30
25% increase	-1.71	-1.27	-2.03	-1.39	-1.63	-1.61
Wisconsin						
10% reduction	.64	.55	.44	.37	.38	.48
25% reduction	1.37	1.17	.93	.78	.80	1.01
40% reduction	1.85	1.59	1.26	1.05	1.08	1.37
25% increase	-2.27	-1.95	-1.55	-1.30	-1.34	1.68
Wyoming						
10% reduction	.67	.89	.72	.79	.83	.78
25% reduction	1.42	1.89	1.54	1.67	1.77	1.66
40% reduction	1.91	2.55	2.08	2.26	2.39	2.24
25% increase	-2.35	-3.10	-2.54	-2.76	-2.91	-2.73

Table D.15. Predicted winter wheat (Roland, cv.) yield adjustment by state, year and April-May ozone concentrations

State and Ozone Assumption	1978	1979	1980	1978-80 Average
Arizona				
10% reduction	N.A.	3.97	3.45	3.71
25% reduction	N.A.	9.67	8.37	9.02
40% reduction	N.A.	14.95	12.89	13.92
25% increase	N.A.	-10.26	- 8.99	- 9.62
Arkansas				
10% reduction	3.23	4.38	3.54	3.71
25% reduction	7.83	10.71	8.61	9.05
40% reduction	12.05	16.60	13.27	13.97
25% increase	- 8.46	-11.25	- 9.23	- 9.65
California				
10% reduction	N.A.	3.66	3.37	3.51
25% reduction	N.A.	8.90	8.17	8.53
40% reduction	N.A.	13.74	12.58	13.16
25% increase	N.A.	- 9.52	- 8.80	- 9.16
Colorado				
10% reduction	3.91	4.01	3.77	3.89
25% reduction	9.51	9.78	9.18	9.49
40% reduction	14.70	15.13	14.18	14.67
25% increase	-10.11	-10.37	- 9.79	-10.09
Idaho				
10% reduction	N.A.	3.66	3.80	3.73
25% reduction	N.A.	8.90	9.26	9.08
40% reduction	N.A.	13.73	14.29	14.01
25% increase	N.A.	- 9.52	- 9.86	- 9.69
Illinois				
10% reduction	3.31	2.32	3.11	2.91
25% reduction	8.02	5.59	7.53	7.05
40% reduction	12.35	8.56	11.58	10.83
25% increase	- 8.65	- 6.18	- 8.16	- 7.66
Indiana				
10% reduction	2.99	2.11	2.20	2.43
25% reduction	7.23	5.07	5.30	5.86
40% reduction	11.11	7.75	8.10	8.99
25% increase	- 7.86	- 5.63	- 5.87	- 6.45
Kansas				
10% reduction	2.82	3.19	2.74	2.91
25% reduction	6.82	7.74	6.62	7.06
40% reduction	10.47	11.91	10.16	10.84
25% increase	- 7.45	- 8.38	- 7.24	- 7.69

Table D.15. (continued)

State and Ozone Assumption	1978	1979	1980	1978-80 Average
Kentucky				
10% reduction	2.89	2.59	2.81	2.76
25% reduction	7.00	6.26	6.79	6.68
40% reduction	10.75	9.60	10.42	10.26
25% increase	- 7.63	- 6.87	- 7.41	- 7.30
Michigan				
10% reduction	2.59	1.84	2.28	2.24
25% reduction	6.24	4.42	5.50	5.39
40% reduction	9.57	6.74	8.41	8.24
25% increase	- 6.85	- 4.94	- 6.08	- 5.96
Missouri				
10% reduction	2.75	3.88	3.79	3.47
25% reduction	6.64	9.45	9.21	8.43
40% reduction	10.19	14.60	14.22	13.00
25% increase	- 7.26	-10.05	- 9.82	- 9.04
Montana				
10% reduction	1.63	3.08	3.78	2.83
25% reduction	3.92	7.46	9.19	6.86
40% reduction	5.97	11.47	14.19	10.54
25% increase	- 4.40	- 8.09	- 9.80	- 7.43
Nebraska				
10% reduction	3.24	3.30	3.15	3.23
25% reduction	7.85	7.99	7.64	7.83
40% reduction	12.08	12.30	11.76	12.05
25% increase	- 8.48	- 8.62	- 8.28	- 8.46
New Mexico				
10% reduction	3.85	3.14	3.15	3.38
25% reduction	9.36	7.61	7.64	8.20
40% reduction	14.46	11.70	11.75	12.64
25% increase	- 9.96	- 8.24	- 8.27	- 8.82
New York				
10% reduction	3.21	2.55	2.79	2.85
25% reduction	7.77	6.15	6.74	6.89
40% reduction	11.96	9.43	10.34	10.58
25% increase	- 8.40	- 6.76	- 7.36	- 7.51
North Carolina				
10% reduction	3.67	3.24	4.27	3.73
25% reduction	8.92	7.85	10.43	9.07
40% reduction	13.76	12.08	16.16	14.00
25% increase	- 9.53	- 8.48	-10.99	- 9.67

Table D.15. (continued)

State and Ozone Assumption	1978	1979	1980	1978-80 Average
Ohio				
10% reduction	2.93	2.51	2.07	2.50
25% reduction	7.09	6.05	4.97	6.04
40% reduction	10.88	9.27	7.59	9.24
25% increase	- 7.71	- 6.66	- 5.53	- 6.63
Oklahoma				
10% reduction	2.94	3.29	2.09	2.77
25% reduction	7.12	7.97	5.03	6.71
40% reduction	10.94	12.27	7.69	10.30
25% increase	- 7.75	- 8.60	- 5.60	- 7.32
Pennsylvania				
10% reduction	3.21	2.27	2.87	2.78
25% reduction	7.77	5.47	6.95	6.73
40% reduction	11.96	8.37	10.67	10.33
25% increase	- 8.41	- 6.05	- 7.58	- 7.35
South Carolina				
10% reduction	4.05	3.79	4.60	4.14
25% reduction	9.87	9.22	11.25	10.11
40% reduction	15.26	14.24	17.45	15.65
25% increase	-10.45	- 9.83	-11.75	-10.68
South Dakota				
10% reduction	2.60	2.61	2.92	2.71
25% reduction	6.27	6.30	7.06	6.54
40% reduction	9.61	9.66	10.84	10.04
25% increase	- 6.88	- 6.91	- 7.69	- 7.16
Tennessee				
10% reduction	3.22	2.48	3.45	3.05
25% reduction	7.80	5.97	8.38	7.38
40% reduction	12.00	9.15	12.92	11.36
25% increase	- 8.43	- 6.58	- 9.01	- 8.01
Texas				
10% reduction	3.16	2.89	2.89	2.98
25% reduction	7.67	7.00	7.00	7.22
40% reduction	11.80	10.75	10.75	11.10
25% increase	- 8.30	- 7.63	- 7.63	- 7.85
Wyoming				
10% reduction	3.68	3.93	3.81	3.80
25% reduction	8.94	9.58	9.26	9.26
40% reduction	13.79	14.80	14.23	14.27
25% increase	- 9.55	-10.17	- 9.88	- 9.86

Table D16. Yield Adjustments for Analysis I:

10% Ozone Reduction

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	1.004	1.026	1.026	.000	1.015	1.004	.000
ARIZONA	1.006	.000	1.017	1.008	1.015	1.004	1.001
ARKANSAS	1.006	1.029	1.033	.000	1.015	1.004	.000
CALIFORNIA	1.006	.000	1.018	1.008	1.014	1.004	1.001
COLORADO	1.006	.000	.000	1.008	1.016	1.004	1.001
CONNECTICUT	1.010	.000	.000	.000	.000	.000	.000
DELAWARE	1.002	1.019	.000	.000	1.012	.000	1.000
FLORIDA	1.002	1.018	1.012	.000	.000	.000	.000
GEORGIA	1.004	1.026	1.026	.000	1.015	1.004	.000
IDAHO	1.004	.000	.000	1.006	1.017	.000	1.001
ILLINOIS	1.004	1.026	.000	.000	1.013	1.004	1.001
INDIANA	1.004	1.026	.000	.000	1.008	1.004	.000
IOWA	1.003	1.022	.000	.000	1.012	1.003	.000
KANSAS	1.004	1.025	.000	.000	1.011	1.003	1.001
KENTUCKY	1.004	1.024	.000	.000	1.011	1.003	1.001
LOUISIANA	1.003	1.023	1.014	.000	1.009	1.003	.000
MAINE	1.002	.000	.000	.000	.000	.000	.000
MARYLAND	1.005	1.027	.000	.000	1.012	.000	1.001
MASSACHUSETTS	1.004	.000	.000	.000	.000	.000	.000
MICHIGAN	1.002	1.020	.000	.000	1.008	.000	1.000
MINNESOTA	1.002	1.021	.000	1.004	1.012	.000	1.000
MISSISSIPPI	1.005	1.027	1.029	.000	1.016	1.004	.000
MISSOURI	1.005	1.027	1.029	.000	1.015	1.004	.000
MONTANA	1.004	.000	.000	1.005	1.013	.000	1.001
NEBRASKA	1.004	1.025	.000	.000	1.013	1.003	1.001
NEVADA	1.006	.000	1.017	1.008	1.015	.000	1.001
NEW HAMPSHIRE	1.003	.000	.000	.000	.000	.000	.000
NEW JERSEY	1.007	1.030	.000	.000	1.013	.000	1.001
NEW MEXICO	1.004	.000	1.014	.000	1.041	1.003	1.001
NEW YORK	1.003	1.022	.000	.000	1.011	.000	1.000
NORTH CAROLINA	1.007	1.031	1.038	.000	1.016	1.005	1.001
NORTH DAKOTA	1.002	1.020	.000	1.003	1.013	.000	1.000
OHIO	1.003	1.023	.000	.000	1.009	.000	1.000
OKLAHOMA	1.004	1.026	1.015	.000	1.011	1.004	1.001
OREGON	1.001	.000	.000	1.002	1.006	.000	1.000
PENNSYLVANIA	1.004	1.024	.000	.000	1.011	1.003	1.001
RHODE ISLAND	1.007	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	1.007	1.030	1.037	.000	1.021	1.005	1.001
SOUTH DAKOTA	1.002	1.022	.000	1.004	1.012	1.003	1.000
TENNESSEE	1.004	1.025	1.025	.000	1.015	1.004	1.001
TEXAS	1.003	1.023	1.013	.000	1.014	1.003	1.000
UTAH	1.007	.000	.000	1.008	1.020	.000	1.001
VERMONT	1.003	.000	.000	.000	.000	.000	.000
VIRGINIA	1.007	1.031	1.038	.000	1.016	1.005	1.001
WASHINGTON	1.001	.000	.000	1.001	1.005	.000	1.000
WEST VIRGINIA	1.003	.000	.000	.000	1.010	.000	1.001
WISCONSIN	1.003	1.021	.000	1.004	1.014	.000	1.000
WYOMING	1.005	.000	.000	1.006	1.017	.000	1.001

Table D17. Yield Adjustments for Analysis I:

25% Ozone Reduction

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	1.009	1.064	1.057	.000	1.034	1.008	.000
ARIZONA	1.012	.000	1.123	1.017	1.033	1.010	1.002
ARKANSAS	1.012	1.072	1.073	.000	1.034	1.010	.000
CALIFORNIA	1.013	.000	1.126	1.017	1.032	1.010	1.002
COLORADO	1.012	.000	.000	1.016	1.037	1.010	1.002
CONNECTICUT	1.012	.000	.000	.000	.000	.000	.000
DELAWARE	1.003	1.046	.000	.000	1.027	.000	1.000
FLORIDA	1.003	1.045	1.027	.000	.000	.000	.000
GEORGIA	1.009	1.064	1.056	.000	1.035	1.008	.000
IDAHO	1.008	.000	.000	1.012	1.038	.000	1.001
ILLINOIS	1.009	1.064	.000	.000	1.029	1.008	1.001
INDIANA	1.009	1.064	.000	.000	1.018	1.008	.000
IOWA	1.006	1.056	.000	.000	1.028	1.006	.000
KANSAS	1.008	1.062	.000	.000	1.024	1.007	1.001
KENTUCKY	1.008	1.061	.000	.000	1.025	1.007	1.001
LOUISIANA	1.006	1.056	1.043	.000	1.020	1.006	.000
MAINE	1.003	.000	.000	.000	.000	.000	.000
MARYLAND	1.010	1.067	.000	.000	1.027	.000	1.002
MASSACHUSETTS	1.009	.000	.000	.000	.000	.000	.000
MICHIGAN	1.004	1.049	.000	.000	1.019	.000	1.001
MINNESOTA	1.005	1.051	.000	1.008	1.026	.000	1.001
MISSISSIPPI	1.010	1.068	1.065	.000	1.037	1.009	.000
MISSOURI	1.010	1.068	1.065	.000	1.038	1.009	.000
MONTANA	1.008	.000	.000	1.011	1.038	.000	1.001
NEBRASKA	1.008	1.061	.000	.000	1.029	1.007	1.001
NEVADA	1.012	.000	1.118	1.016	1.033	.000	1.002
NEW HAMPSHIRE	1.006	.000	.000	.000	.000	.000	.000
NEW JERSEY	1.014	1.076	.000	.000	1.030	.000	1.002
NEW MEXICO	1.008	.000	1.089	.000	1.029	1.008	1.001
NEW YORK	1.005	1.054	.000	.000	1.025	.000	1.001
NORTH CAROLINA	1.015	1.078	1.086	.000	1.044	1.011	1.003
NORTH DAKOTA	1.004	1.050	.000	1.007	1.029	.000	1.001
OHIO	1.006	1.057	.000	.000	1.016	.000	1.001
OKLAHOMA	1.009	1.065	1.033	.000	1.017	1.008	1.001
OREGON	1.002	.000	.000	1.004	1.014	.000	1.000
PENNSYLVANIA	1.008	1.061	.000	.000	1.026	1.007	1.001
RHODE ISLAND	1.014	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	1.014	1.076	1.083	.000	1.049	1.011	1.002
SOUTH DAKOTA	1.006	1.056	.000	1.009	1.026	1.006	1.001
TENNESSEE	1.009	1.064	1.056	.000	1.033	1.008	1.001
TEXAS	1.006	1.057	1.031	.000	1.026	1.007	1.001
UTAH	1.013	.000	.000	1.018	1.047	.000	1.002
VERMONT	1.007	.000	.000	.000	.000	.000	.000
VIRGINIA	1.015	1.078	1.086	.000	1.036	1.011	1.003
WASHINGTON	1.001	.000	.000	1.002	1.012	.000	1.000
WEST VIRGINIA	1.007	.000	.000	.000	1.023	.000	1.001
WISCONSIN	1.005	1.053	.000	1.008	1.043	.000	1.001
WYOMING	1.009	.000	.000	1.013	1.038	.000	1.001

Table D18. Yield Adjustments for Analysis I:

40% Ozone Reduction

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	1.012	1.104	1.081	.000	1.050	1.012	.000
ARIZONA	1.012	.000	1.130	1.023	1.039	1.014	1.002
ARKANSAS	1.016	1.115	1.104	.000	1.050	1.014	.000
CALIFORNIA	1.016	.000	1.179	1.024	1.046	1.015	1.003
COLORADO	1.015	.000	.000	1.022	1.054	1.014	1.002
CONNECTICUT	1.025	.000	.000	.000	.000	.000	.000
DELAWARE	1.005	1.073	.000	.000	1.040	.000	1.001
FLORIDA	1.004	1.071	1.038	.000	.000	.000	.000
GEORGIA	1.011	1.102	1.080	.000	1.050	1.011	.000
IDAHO	1.010	.000	.000	1.016	1.055	.000	1.001
ILLINOIS	1.011	1.102	.000	.000	1.041	1.012	1.002
INDIANA	1.011	1.102	.000	.000	1.026	1.011	.000
IOWA	1.010	1.089	.000	.000	1.040	1.009	.000
KANSAS	1.010	1.098	.000	.000	1.035	1.011	1.001
KENTUCKY	1.010	1.097	.000	.000	1.036	1.010	1.001
LOUISIANA	1.010	1.089	1.061	.000	1.029	1.009	.000
MAINE	1.004	.000	.000	.000	.000	.000	.000
MARYLAND	1.013	1.107	.000	.000	1.039	.000	1.002
MASSACHUSETTS	1.011	.000	.000	.000	.000	.000	.000
MICHIGAN	1.005	1.077	.000	.000	1.027	.000	1.001
MINNESOTA	1.006	1.082	.000	1.010	1.038	.000	1.001
MISSISSIPPI	1.014	1.109	1.092	.000	1.054	1.013	.000
MISSOURI	1.014	1.109	1.092	.000	1.054	1.012	.000
MONTANA	1.010	.000	.000	1.015	1.054	.000	1.001
NEBRASKA	1.010	1.097	.000	.000	1.042	1.011	1.001
NEVADA	1.015	.000	1.168	1.022	1.048	.000	1.002
NEW HAMPSHIRE	1.008	.000	.000	.000	.000	.000	.000
NEW JERSEY	1.018	1.121	.000	.000	1.042	1.011	1.002
NEW MEXICO	1.011	.000	1.126	.000	1.042	1.011	1.002
NEW YORK	1.007	1.086	.000	.000	1.036	.000	1.001
NORTH CAROLINA	1.020	1.124	1.122	.000	1.064	1.016	1.003
NORTH DAKOTA	1.010	1.079	.000	1.001	1.041	.000	1.001
OHIO	1.008	1.091	.000	.000	1.024	.000	1.001
OKLAHOMA	1.012	1.104	1.056	.000	1.024	1.012	1.002
OREGON	1.003	.000	.000	1.001	1.020	.000	1.000
PENNSYLVANIA	1.010	1.097	.000	.000	1.037	1.011	1.001
RHODE ISLAND	1.018	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	1.019	1.122	1.118	.000	1.071	1.016	1.003
SOUTH DAKOTA	1.010	1.089	.000	1.013	1.038	1.009	1.001
TENNESSEE	1.011	1.102	1.080	.000	1.048	1.011	1.002
TEXAS	1.008	1.091	1.048	.000	1.038	1.009	1.001
UTAH	1.018	.000	.000	1.025	1.068	.000	1.003
VERMONT	1.090	.000	.000	.000	.000	.000	.000
VIRGINIA	1.020	1.125	1.123	.000	1.052	1.016	1.003
WASHINGTON	1.002	.000	.000	1.000	1.017	.000	1.000
WEST VIRGINIA	1.009	.000	.000	.000	1.033	.000	1.001
WISCONSIN	1.007	1.085	.000	1.011	1.047	.000	1.001
WYOMING	1.012	.000	.000	1.018	1.055	.000	1.002

Table D19. Yield Adjustments for Analysis I:

25% Ozone Increase

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	.984	.936	.918	.000	.955	.989	.000
ARIZONA	.977	.000	.840	.974	.957	.967	.996
ARKANSAS	.977	.929	.901	.000	.955	.967	.000
CALIFORNIA	.976	.000	.837	.973	.958	.987	.996
COLORADO	.978	.000	.000	.975	.951	.987	.996
CONNECTICUT	.964	.000	.000	.000	.000	.000	.000
DELAWARE	.994	.954	.000	.000	.964	.000	.999
FLORIDA	.994	.965	.961	.000	.000	.000	.000
GEORGIA	.935	.937	.921	.000	.955	.989	.000
IDAHO	.985	.000	.000	.981	.951	.000	.997
ILLINOIS	.983	.937	.000	.000	.962	.989	.997
INDIANA	.984	.937	.000	.000	.976	.989	.000
IOWA	.989	.944	.000	.000	.964	.992	.000
KANSAS	.981	.939	.000	.000	.968	.990	.998
KENTUCKY	.986	.940	.000	.000	.967	.990	.998
LOUISIANA	.989	.944	.939	.000	.973	.992	.000
MAINE	.994	.000	.000	.000	.000	.000	.000
MARYLAND	.981	.934	.000	.000	.964	.000	.997
MASSACHUSETTS	.984	.000	.000	.000	.000	.000	.000
MICHIGAN	.993	.951	.000	.000	.975	.000	.999
MINNESOTA	.991	.949	.000	.988	.965	.000	.999
MISSISSIPPI	.980	.933	.911	.000	.952	.988	.000
MISSOURI	.980	.938	.911	.000	.951	.988	.000
MONTANA	.986	.000	.000	.982	.951	.000	.998
NEBRASKA	.986	.939	.000	.000	.961	.990	.998
NEVADA	.978	.000	.846	.975	.957	.000	.996
NEW HAMPSHIRE	.988	.000	.000	.000	.000	.000	.000
NEW JERSEY	.974	.926	.000	.000	.961	.000	.995
NEW MEXICO	.985	.000	.880	.000	.962	.990	.997
NEW YORK	.989	.946	.000	.000	.967	.000	.998
NORTH CAROLINA	.972	.924	.885	.000	.943	.985	.994
NORTH DAKOTA	.992	.950	.000	.989	.963	.000	.999
OHIO	.988	.943	.000	.000	.978	.000	.998
OKLAHOMA	.983	.936	.961	.000	.978	.989	.997
OREGON	.996	.000	.000	.993	.981	.000	.999
PENNSYLVANIA	.986	.939	.000	.000	.966	.990	.998
RHODE ISLAND	.978	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	.973	.925	.889	.000	.937	.985	.995
SOUTH DAKOTA	.989	.944	.000	.985	.965	.992	.998
TENNESSEE	.984	.937	.922	.000	.957	.989	.997
TEXAS	.988	.943	.966	.000	.966	.990	.998
UTAH	.975	.000	.000	.972	.940	.000	.995
VERMONT	.988	.000	.000	.000	.000	.000	.000
VIRGINIA	.972	.924	.884	.000	.953	.985	.994
WASHINGTON	.998	.000	.000	.996	.984	.000	.999
WEST VIRGINIA	.987	.000	.000	.000	.969	.000	.998
WISCONSIN	.980	.947	.000	.987	.957	.000	.999
WYOMING	.983	.000	.000	.979	.951	.000	.997

Table D20. Yield Adjustments for Analysis II:

10% Ozone Reduction

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	1.004	1.027	1.026	.000	1.015	1.004	.000
ARIZONA	1.006	.000	1.017	1.008	1.015	1.004	1.001
ARKANSAS	1.006	1.029	1.033	.000	1.015	1.004	.000
CALIFORNIA	1.006	.000	1.018	1.008	1.014	1.004	1.001
COLORADO	1.006	.000	.000	1.008	1.016	1.004	1.001
CONNECTICUT	1.010	.000	.000	.000	.000	.000	.000
DELAWARE	1.002	1.017	.000	.000	1.012	.000	1.000
FLORIDA	1.002	1.017	1.012	.000	.000	.000	.000
GEORGIA	1.004	1.026	1.026	.000	1.015	1.004	.000
IDAHO	1.004	.000	.000	1.006	1.017	.000	1.001
ILLINOIS	1.004	1.027	.000	.000	1.013	1.004	1.001
INDIANA	1.004	1.026	.000	.000	1.008	1.004	.000
IOWA	1.003	1.022	.000	.000	1.012	1.003	.000
KANSAS	1.004	1.025	.000	.000	1.011	1.003	1.001
KENTUCKY	1.004	1.025	.000	.000	1.011	1.003	1.001
LOUISIANA	1.003	1.022	1.014	.000	1.009	1.003	.000
MAINE	1.002	.000	.000	.000	.000	.000	.000
MARYLAND	1.005	1.028	.000	.000	1.012	.000	1.001
MASSACHUSETTS	1.004	.000	.000	.000	.000	.000	.000
MICHIGAN	1.002	1.019	.000	.000	1.008	.000	1.000
MINNESOTA	1.002	1.020	.000	1.004	1.012	.000	1.000
MISSISSIPPI	1.005	1.029	1.029	.000	1.016	1.004	.000
MISSOURI	1.005	1.029	1.029	.000	1.015	1.004	.000
MONTANA	1.004	.000	.000	1.005	1.013	.000	1.001
NEBRASKA	1.004	1.025	.000	.000	1.013	1.003	1.001
NEVADA	1.006	.000	1.017	1.008	1.015	.000	1.001
NEW HAMPSHIRE	1.003	.000	.000	.000	.000	.000	.000
NEW JERSEY	1.007	1.033	.000	.000	1.013	.000	1.001
NEW MEXICO	1.004	.000	1.014	.000	1.041	1.003	1.001
NEW YORK	1.003	1.021	.000	.000	1.011	.000	1.000
NORTH CAROLINA	1.007	1.034	1.038	1.003	1.016	1.005	1.001
NORTH DAKOTA	1.002	1.099	.000	.000	1.013	.000	1.000
OHIO	1.003	1.023	.000	.000	1.009	.000	1.000
OKLAHOMA	1.004	1.027	1.015	.000	1.011	1.004	1.001
OREGON	1.001	.000	.000	1.002	1.006	.000	1.000
PENNSYLVANIA	1.004	1.025	.000	.000	1.011	1.003	1.001
RHODE ISLAND	1.007	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	1.007	1.033	1.037	.000	1.021	1.005	1.001
SOUTH DAKOTA	1.002	1.022	.000	1.004	1.012	1.003	1.000
TENNESSEE	1.004	1.026	1.025	.000	1.015	1.004	1.001
TEXAS	1.003	1.023	1.013	.000	1.014	1.003	1.000
UTAH	1.007	.000	.000	1.008	1.020	.000	1.001
VERMONT	1.003	.000	.000	.000	.000	.000	.000
VIRGINIA	1.007	1.034	1.038	.000	1.016	1.005	1.001
WASHINGTON	1.001	.000	.000	1.001	1.005	.000	1.000
WEST VIRGINIA	1.003	.000	.000	.000	1.010	.000	1.001
WISCONSIN	1.003	1.021	.000	1.004	1.014	.000	1.000
WYOMING	1.005	.000	.000	1.006	1.017	.000	1.001

Table D21. Yield Adjustments for Analysis II:

25% Ozone Reduction

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	1.009	1.064	1.057	.000	1.034	1.008	.000
ARIZONA	1.012	.000	1.123	1.017	1.033	1.010	1.002
ARKANSAS	1.012	1.075	1.073	.000	1.034	1.010	.000
CALIFORNIA	1.013	.000	1.126	1.017	1.032	1.010	1.002
COLORADO	1.012	.000	.000	1.016	1.037	1.010	1.002
CONNECTICUT	1.012	.000	.000	.000	.000	.000	.000
DELAWARE	1.003	1.042	.000	.000	1.027	.000	1.000
FLORIDA	1.003	1.041	1.027	.000	.000	.000	.000
GEORGIA	1.009	1.064	1.056	.000	1.035	1.008	.000
IDAHO	1.008	.000	.000	1.012	1.038	.000	1.001
ILLINOIS	1.009	1.064	.000	.000	1.029	1.008	1.001
INDIANA	1.009	1.064	.000	.000	1.018	1.008	.000
IOWA	1.006	1.054	.000	.000	1.028	1.006	.000
KANSAS	1.008	1.061	.000	.000	1.024	1.007	1.001
KENTUCKY	1.008	1.060	.000	.000	1.025	1.007	1.001
LOUISIANA	1.006	1.054	1.043	.000	1.020	1.006	.000
MAINE	1.003	.000	.000	.000	.000	.000	.000
MARYLAND	1.010	1.068	.000	.000	1.027	.000	1.002
MASSACHUSETTS	1.009	.000	.000	.000	.000	.000	.000
MICHIGAN	1.004	1.045	.000	.000	1.019	.000	1.001
MINNESOTA	1.005	1.048	.000	.000	1.026	.000	1.001
MISSISSIPPI	1.010	1.070	1.065	.000	1.037	1.009	.000
MISSOURI	1.010	1.069	1.065	.000	1.038	1.009	.000
MONTANA	1.008	.000	.000	1.011	1.038	.000	1.001
NEBRASKA	1.008	1.060	.000	.000	1.029	1.007	1.001
NEVADA	1.012	.000	1.118	1.016	1.033	.000	1.002
NEW HAMPSHIRE	1.006	.000	.000	.000	.000	.000	.000
NEW JERSEY	1.014	1.080	.000	.000	1.030	.000	1.002
NEW MEXICO	1.008	.000	1.089	.000	1.029	1.008	1.001
NEW YORK	1.005	1.051	.000	.000	1.025	.000	1.001
NORTH CAROLINA	1.015	1.082	1.086	.000	1.044	1.011	1.003
NORTH DAKOTA	1.004	1.046	.000	1.007	1.029	.000	1.001
OHIO	1.006	1.055	.000	.000	1.016	.000	1.001
OKLAHOMA	1.009	1.065	1.033	.000	1.017	1.008	1.001
OREGON	1.002	.000	.000	1.004	1.014	.000	1.000
PENNSYLVANIA	1.080	1.060	.000	.000	1.026	1.007	1.001
RHODE ISLAND	1.014	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	1.014	1.081	1.083	.000	1.049	1.011	1.002
SOUTH DAKOTA	1.006	1.054	.000	1.009	1.026	1.006	1.001
TENNESSEE	1.009	1.064	1.056	.000	1.033	1.008	1.001
TEXAS	1.006	1.056	1.031	.000	1.026	1.007	1.001
UTAH	1.013	.000	.000	1.018	1.047	.000	1.002
VERMONT	1.007	.000	.000	.000	.000	.000	.000
VIRGINIA	1.015	1.083	1.086	.000	1.036	1.011	1.003
WASHINGTON	1.001	.000	.000	1.002	1.012	.000	1.000
WEST VIRGINIA	1.007	.000	.000	.000	1.023	.000	1.001
WISCONSIN	1.005	1.051	.000	1.008	1.043	.000	1.001
WYOMING	1.009	.000	.000	1.013	1.038	.000	1.001

Table D22. Yield Adjustments for Analysis II:

40% Ozone Reduction

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	1.012	1.099	1.081	.000	1.050	1.012	.000
ARIZONA	1.012	.000	1.130	1.023	1.048	1.014	1.002
ARKANSAS	1.016	1.116	1.104	.000	1.050	1.014	.000
CALIFORNIA	1.016	.000	1.179	1.024	1.046	1.015	1.003
COLORADO	1.015	.000	.000	1.022	1.054	1.014	1.002
CONNECTICUT	1.025	.000	.000	.000	.000	.000	.000
DELAWARE	1.005	1.064	.000	.000	1.040	.000	1.001
FLORIDA	1.004	1.062	1.038	.000	.000	.000	.000
GEORGIA	1.011	1.099	1.080	.000	1.050	1.011	.000
IDAHO	1.010	.000	.000	1.016	1.055	.000	1.001
ILLINOIS	1.011	1.100	.000	.000	1.041	1.012	1.002
INDIANA	1.011	1.098	.000	.000	1.026	1.009	.000
IOWA	1.010	1.083	.000	.000	1.040	1.011	.000
KANSAS	1.010	1.094	.000	.000	1.035	1.010	1.001
KENTUCKY	1.010	1.092	.000	.000	1.036	1.009	1.001
LOUISIANA	1.010	1.083	1.061	.000	1.029	.000	.000
MAINE	1.004	.000	.000	.000	.000	.000	.000
MARYLAND	1.013	1.105	.000	.000	1.039	.000	1.002
MASSACHUSETTS	1.011	.000	.000	.000	.000	.000	.000
MICHIGAN	1.005	1.069	.000	.000	1.027	.000	1.001
MINNESOTA	1.006	1.074	.000	1.010	1.038	.000	1.001
MISSISSIPPI	1.014	1.107	1.092	.000	1.054	1.013	.000
MISSOURI	1.014	1.107	1.092	.000	1.054	1.013	.000
MONTANA	1.010	.000	.000	1.015	1.054	.000	1.001
NEBRASKA	1.010	1.093	.000	.000	1.042	1.011	1.001
NEVADA	1.015	.000	1.168	1.022	1.048	.000	1.002
NEW HAMPSHIRE	1.008	.000	.000	.000	.000	.000	.000
NEW JERSEY	1.018	1.123	.000	.000	1.043	.000	1.003
NEW MEXICO	1.011	.000	1.126	.000	1.042	1.011	1.002
NEW YORK	1.007	1.079	.000	.000	1.036	.000	1.001
NORTH CAROLINA	1.020	1.128	1.122	.000	1.064	1.016	1.003
NORTH DAKOTA	1.010	1.071	.000	1.001	1.450	.000	1.001
OHIO	1.008	1.085	.000	.000	1.024	.000	1.001
OKLAHOMA	1.012	1.101	1.056	.000	1.024	1.012	1.002
OREGON	1.003	.000	.000	1.001	1.020	.000	1.000
PENNSYLVANIA	1.010	1.093	.000	.000	1.037	1.011	1.001
RHODE ISLAND	1.018	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	1.019	1.125	1.118	.000	1.071	1.016	1.003
SOUTH DAKOTA	1.010	1.083	.000	1.013	1.038	1.009	1.001
TENNESSEE	1.011	1.098	1.080	.000	1.048	1.011	1.002
TEXAS	1.008	1.085	1.048	.000	1.038	1.009	1.001
UTAH	1.018	.000	.000	1.025	1.068	.000	1.003
VERMONT	1.090	.000	.000	.000	.000	.000	.000
VIRGINIA	1.020	1.128	1.123	.000	1.052	1.016	1.003
WASHINGTON	1.002	.000	.000	1.000	1.017	.000	1.000
WEST VIRGINIA	1.009	.000	.000	.000	1.033	.000	1.001
WISCONSIN	1.007	1.078	.000	1.011	1.047	.000	1.001
WYOMING	1.012	.000	.000	1.018	1.055	.000	1.002

Table D23. Yield Adjustments for Analysis II:

25% Ozone Increase

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	.984	.930	.918	.000	.955	.939	.000
ARIZONA	.977	.000	.840	.974	.957	.967	.996
ARKANSAS	.977	.920	.901	.000	.955	.967	.000
CALIFORNIA	.976	.000	.837	.973	.958	.987	.996
COLORADO	.978	.000	.000	.975	.951	.987	.996
CONNECTICUT	.964	.000	.000	.000	.000	.000	.000
DELAWARE	.994	.954	.000	.000	.964	.000	.999
FLORIDA	.994	.955	.961	.000	.000	.000	.000
GEORGIA	.935	.931	.921	.000	.955	.989	.000
IDAHO	.985	.000	.000	.981	.951	.000	.997
ILLINOIS	.983	.931	.000	.000	.962	.989	.997
INDIANA	.984	.931	.000	.000	.976	.989	.000
IOWA	.989	.941	.000	.000	.964	.992	.000
KANSAS	.981	.934	.000	.000	.968	.990	.998
KENTUCKY	.986	.935	.000	.000	.967	.990	.998
LOUISIANA	.989	.941	.929	.000	.973	.992	.000
MAINE	.994	.000	.000	.000	.000	.000	.000
MARYLAND	.981	.927	.000	.000	.964	.000	.997
MASSACHUSETTS	.984	.000	.000	.000	.000	.000	.000
MICHIGAN	.993	.951	.000	.000	.975	.000	.999
MINNESOTA	.991	.947	.000	.988	.965	.000	.999
MISSISSIPPI	.980	.925	.911	.000	.952	.988	.000
MISSOURI	.980	.925	.911	.000	.957	.988	.000
MONTANA	.986	.000	.000	.982	.951	.000	.998
NEBRASKA	.986	.935	.000	.000	.961	.990	.998
NEVADA	.978	.000	.846	.975	.957	.000	.996
NEW HAMPSHIRE	.988	.000	.000	.000	.000	.000	.000
NEW JERSEY	.974	.915	.000	.000	.961	.000	.995
NEW MEXICO	.985	.000	.880	.000	.962	.990	.997
NEW YORK	.989	.944	.000	.000	.976	.000	.998
NORTH CAROLINA	.972	.913	.885	.000	.943	.985	.994
NORTH DAKOTA	.992	.949	.000	.989	.963	.000	.999
OHIO	.988	.940	.000	.000	.978	.000	.998
OKLAHOMA	.983	.929	.961	.000	.978	.989	.997
OREGON	.996	.000	.000	.993	.981	.000	.999
PENNSYLVANIA	.986	.935	.000	.000	.966	.990	.998
RHODE ISLAND	.978	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	.973	.914	.889	.000	.937	.985	.995
SOUTH DAKOTA	.989	.941	.000	.985	.965	.992	.998
TENNESSEE	.984	.931	.992	.000	.957	.989	.997
TEXAS	.988	.940	.966	.000	.966	.990	.998
UTAH	.975	.000	.000	.972	.940	.000	.995
VERMONT	.988	.000	.000	.000	.000	.000	.000
VIRGINIA	.972	.912	.884	.000	.953	.985	.994
WASHINGTON	.998	.000	.000	.996	.984	.000	.999
WEST VIRGINIA	.987	.000	.000	.000	.969	.000	.998
WISCONSIN	.980	.945	.000	.987	.957	.000	.999
WYOMING	.983	.000	.000	.979	.951	.000	.997

Table D24. Yield Adjustments for Analysis III:

10% Ozone Reduction

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	1.007	1.037	1.026	.000	1.036	1.004	.000
ARIZONA	1.009	.000	1.017	1.008	1.035	1.004	1.001
ARKANSAS	1.009	1.041	1.033	.000	1.035	1.004	.000
CALIFORNIA	1.010	.000	1.018	1.008	1.034	1.004	1.001
COLORADO	1.009	.000	.000	1.008	1.038	1.004	1.001
CONNECTICUT	1.014	.000	.000	.000	.000	.000	.000
DELAWARE	1.003	1.030	.000	.000	1.030	.000	1.000
FLORIDA	1.003	1.029	1.012	.000	.000	.000	.000
GEORGIA	1.007	1.037	1.026	.000	1.036	1.004	.000
IDAHO	1.006	.000	.000	1.006	1.038	.000	1.001
ILLINOIS	1.007	1.037	.000	.000	1.031	1.004	1.001
INDIANA	1.007	1.037	.000	.000	1.022	1.004	.000
IOWA	1.005	1.034	.000	.000	1.030	1.003	.000
KANSAS	1.006	1.036	.000	.000	1.027	1.003	1.001
KENTUCKY	1.006	1.036	.000	.000	1.028	1.003	1.001
LOUISIANA	1.005	1.034	.000	.000	1.024	1.003	.000
MAINE	1.003	.000	.000	.000	.000	.000	.000
MARYLAND	1.008	1.039	.000	.000	1.030	.000	1.001
MASSACHUSETTS	1.007	.000	.000	.000	.000	.000	.000
MICHIGAN	1.004	1.031	.000	.000	1.023	.000	1.000
MINNESOTA	1.004	1.032	.000	1.004	1.029	.000	1.000
MISSISSIPPI	1.008	1.039	1.029	.000	1.038	1.004	.000
MISSOURI	1.008	1.039	1.029	.000	1.038	1.004	.000
MONTANA	1.006	.000	.000	1.005	1.038	.000	1.001
NEBRASKA	1.006	1.036	.000	.000	1.032	1.003	1.001
NEVADA	1.009	.000	1.017	1.008	1.035	.000	1.001
NEW HAMPSHIRE	1.005	.000	.000	.000	.000	.000	.000
NEW JERSEY	1.010	1.042	.000	.000	1.032	.000	1.001
NEW MEXICO	1.007	.000	1.014	.000	1.032	1.003	1.001
NEW YORK	1.005	1.033	.000	.000	1.028	.000	1.000
NORTH CAROLINA	1.011	1.043	1.038	.000	1.043	1.005	1.001
NORTH DAKOTA	1.004	1.031	.000	1.003	1.031	.000	1.000
OHIO	1.005	1.034	.000	.000	1.021	.000	1.000
OKLAHOMA	1.007	1.038	1.015	.000	1.021	1.004	1.001
OREGON	1.002	.000	.000	1.002	1.019	.000	1.000
PENNSYLVANIA	1.006	1.036	.000	.000	1.029	1.003	1.001
RHODE ISLAND	1.010	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	1.011	1.042	1.037	.000	1.046	1.005	1.001
SOUTH DAKOTA	1.005	1.034	.000	1.004	1.029	1.003	1.000
TENNESSEE	1.007	1.037	1.025	.000	1.035	1.004	1.001
TEXAS	1.005	1.034	.000	.000	1.029	1.003	1.000
UTAH	1.010	.000	.000	1.008	1.044	.000	1.001
VERMONT	1.005	.000	.000	.000	.000	.000	.000
VIRGINIA	1.011	1.043	1.038	.000	1.037	1.005	1.001
WASHINGTON	1.001	.000	.000	1.001	1.016	.000	1.000
WEST VIRGINIA	1.006	.000	.000	.000	1.027	.000	1.001
WISCONSIN	1.004	1.033	.000	1.004	1.034	.000	1.000
WYOMING	1.007	.000	.000	1.006	1.038	.000	1.001

Table D25. Yield Adjustments for Analysis III:

25% Ozone Reduction

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	1.015	1.097	1.057	.000	1.086	1.008	.000
ARIZONA	1.020	.000	1.123	1.017	1.084	1.010	1.002
ARKANSAS	1.020	1.041	1.073	.000	1.086	1.010	.000
CALIFORNIA	1.020	.000	1.126	1.017	1.082	1.010	1.002
COLORADO	1.019	.000	.000	1.016	1.092	1.010	1.002
CONNECTICUT	1.030	.000	.000	.000	.000	.000	.000
DELAWARE	1.007	1.076	.000	.000	1.073	.000	1.000
FLORIDA	1.006	1.075	1.027	.000	.000	.000	.000
GEORGIA	1.015	1.097	1.056	.000	1.087	1.008	.000
IDAHO	1.014	.000	.000	1.012	1.093	.000	1.001
ILLINOIS	1.015	1.097	.000	.000	1.075	1.008	1.001
INDIANA	1.015	1.097	.000	.000	1.053	1.008	.000
IOWA	1.011	1.088	.000	.000	1.073	1.006	.000
KANSAS	1.013	1.094	.000	.000	1.066	1.007	1.001
KENTUCKY	1.013	1.093	.000	.000	1.068	1.007	1.001
LOUISIANA	1.011	1.088	1.043	.000	1.058	1.006	.000
MAINE	1.006	.000	.000	.000	.000	.000	.000
MARYLAND	1.017	1.100	.000	.000	1.072	.000	1.002
MASSACHUSETTS	1.015	.000	.000	.000	.000	.000	.000
MICHIGAN	1.007	1.079	.000	.000	1.055	.000	1.001
MINNESOTA	1.009	1.082	.000	1.008	1.070	.000	1.001
MISSISSIPPI	1.017	1.101	1.065	.000	1.091	1.009	.000
MISSOURI	1.017	1.101	1.065	.000	1.092	1.009	.000
MONTANA	1.013	.000	.000	1.011	1.092	.000	1.001
NEBRASKA	1.013	1.094	.000	.000	1.076	1.007	1.001
NEVADA	1.019	.000	1.118	1.016	1.084	.000	1.002
NEW HAMPSHIRE	1.011	.000	.000	.000	.000	.000	.000
NEW JERSEY	1.022	1.109	.000	.000	1.078	.000	1.002
NEW MEXICO	1.014	.000	1.089	.000	1.076	1.008	1.001
NEW YORK	1.010	1.086	.000	.000	1.067	.000	1.001
NORTH CAROLINA	1.024	1.111	1.086	.000	1.104	1.011	1.003
NORTH DAKOTA	1.008	1.080	.000	1.007	1.075	.000	1.001
OHIO	1.011	1.089	.000	.000	1.050	.000	1.001
OKLAHOMA	1.015	1.098	1.033	.000	1.050	1.008	1.001
OREGON	1.005	.000	.000	1.004	1.044	.000	1.000
PENNSYLVANIA	1.013	1.094	.000	.000	1.070	1.007	1.001
RHODE ISLAND	1.022	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	1.023	1.110	1.083	.000	1.113	1.011	1.002
SOUTH DAKOTA	1.011	1.088	.000	1.009	1.071	1.006	1.001
TENNESSEE	1.015	1.097	1.056	.000	1.084	1.008	1.001
TEXAS	1.011	1.089	1.031	.000	1.070	1.007	1.001
UTAH	1.022	.000	.000	1.018	1.110	.000	1.002
VERMONT	1.011	.000	.000	.000	.000	.000	.000
VIRGINIA	1.024	1.112	1.086	.000	1.089	1.011	1.003
WASHINGTON	1.003	.000	.000	1.002	1.039	.000	1.000
WEST VIRGINIA	1.012	.000	.000	.000	1.064	.000	1.001
WISCONSIN	1.009	1.085	.000	1.008	1.083	.000	1.001
WYOMING	1.015	.000	.000	1.013	1.093	.000	1.001

Table D26. Yield Adjustments for Analysis III:

40% Ozone Reduction

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	1.020	1.162	1.081	.000	1.133	1.012	.000
ARIZONA	1.027	.000	1.130	1.023	1.129	1.014	1.002
ARKANSAS	1.027	1.176	1.104	.000	1.133	1.014	.000
CALIFORNIA	1.028	.000	1.179	1.024	1.126	1.015	1.003
COLORADO	1.026	.000	.000	1.022	1.142	1.014	1.002
CONNECTICUT	1.041	.000	.000	.000	.000	.000	.000
DELAWARE	1.009	1.126	.000	.000	1.112	.000	1.001
FLORIDA	1.008	1.124	1.038	.000	.000	.000	.000
GEORGIA	1.020	1.161	1.080	.000	1.134	1.011	.000
IDAHO	1.018	.000	.000	1.016	1.143	.000	1.001
ILLINOIS	1.020	1.162	.000	.000	1.116	1.011	1.002
INDIANA	1.020	1.161	.000	.000	1.081	1.009	.000
IOWA	1.014	1.146	.000	.000	1.112	1.011	.000
KANSAS	1.018	1.157	.000	.000	1.102	1.010	1.001
KENTUCKY	1.017	1.155	.000	.000	1.104	1.009	1.001
LOUISIANA	1.041	1.145	1.061	.000	1.088	.000	.000
MAINE	1.008	.000	.000	.000	.000	.000	.000
MARYLAND	1.022	1.167	.000	.000	1.111	.000	1.002
MASSACHUSETTS	1.010	.000	.000	.000	.000	.000	.000
MICHIGAN	1.010	1.131	.000	.000	1.084	.000	.000
MINNESOTA	1.011	1.137	.000	1.010	1.108	.000	1.001
MISSISSIPPI	1.023	1.169	1.092	.000	1.141	1.013	.000
MISSOURI	1.023	1.169	1.092	.000	1.142	1.013	.000
MONTANA	1.018	.000	.000	1.015	1.142	.000	1.001
NEBRASKA	1.018	1.156	.000	.000	1.118	1.011	1.001
NEVADA	1.026	.000	1.168	1.022	1.129	.000	1.002
NEW HAMPSHIRE	1.015	.000	.000	.000	.000	.000	.000
NEW JERSEY	1.030	1.183	.000	.000	1.119	.000	1.003
NEW MEXICO	1.019	.000	1.126	.000	1.118	1.011	1.002
NEW YORK	1.013	1.142	.000	.000	1.103	.000	1.001
NORTH CAROLINA	1.032	1.187	1.122	.000	1.162	1.016	1.003
NORTH DAKOTA	1.011	1.133	.000	1.001	1.115	.000	1.001
OHIO	1.015	1.148	.000	.000	1.076	.000	1.001
OKLAHOMA	1.021	1.163	1.056	.000	1.077	1.012	1.002
OREGON	1.006	.000	.000	1.001	1.068	.000	1.000
PENNSYLVANIA	1.018	1.156	.000	.000	1.107	1.011	1.001
RHODE ISLAND	1.030	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	1.031	1.184	1.118	.000	1.175	1.016	1.003
SOUTH DAKOTA	1.014	1.146	.000	1.013	1.108	1.009	1.001
TENNESSEE	1.020	1.161	1.080	.000	1.129	1.011	1.002
TEXAS	1.015	1.149	1.048	.000	1.108	1.009	1.001
UTAH	1.029	.000	.000	1.025	1.168	.000	1.003
VERMONT	1.015	.000	.000	.000	.000	.000	.000
VIRGINIA	1.032	1.187	1.123	.000	1.138	1.016	1.003
WASHINGTON	1.003	.000	.000	1.000	1.059	.000	1.000
WEST VIRGINIA	1.017	.000	.000	.000	1.098	.000	1.001
WISCONSIN	1.013	1.141	.000	1.011	1.128	.000	1.001
WYOMING	1.021	.000	.000	1.018	1.142	.000	1.002

Table D27. Yield Adjustments for Analysis III:

25% Ozone Increase

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	.976	.914	.918	.000	.910	.989	.000
ARIZONA	.967	.000	.840	.974	.910	.967	.996
ARKANSAS	.968	.908	.901	.000	.908	.967	.000
CALIFORNIA	.967	.000	.837	.973	.912	.987	.996
COLORADO	.969	.000	.000	.975	.902	.987	.996
CONNECTICUT	.952	.000	.000	.000	.000	.000	.000
DELAWARE	.989	.931	.000	.000	.921	.000	.999
FLORIDA	.990	.933	.961	.000	.000	.000	.000
GEORGIA	.976	.914	.921	.000	.907	.989	.000
IDAHO	.978	.000	.000	.981	.901	.000	.997
ILLINOIS	.976	.914	.000	.000	.918	.989	.997
INDIANA	.976	.915	.000	.000	.941	.989	.000
IOWA	.983	.922	.000	.000	.921	.992	.000
KANSAS	.978	.917	.000	.000	.928	.990	.998
KENTUCKY	.979	.918	.000	.000	.926	.990	.998
LOUISIANA	.982	.922	.939	.000	.936	.992	.000
MAINE	.990	.000	.000	.000	.000	.000	.000
MARYLAND	.973	.912	.000	.000	.921	.000	.997
MASSACHUSETTS	.976	.000	.000	.000	.000	.000	.000
MICHIGAN	.988	.929	.000	.000	.939	.000	.999
MINNESOTA	.989	.926	.000	.988	.923	.000	.999
MISSISSIPPI	.972	.911	.911	.000	.903	.988	.000
MISSOURI	.972	.911	.911	.000	.902	.988	.000
MONTANA	.979	.000	.000	.982	.902	.000	.998
NEBRASKA	.978	.917	.000	.000	.917	.990	.998
NEVADA	.969	.000	.846	.975	.910	.000	.996
NEW HAMPSHIRE	.982	.000	.000	.000	.000	.000	.000
NEW JERSEY	.964	.904	.000	.000	.916	.000	.995
NEW MEXICO	.977	.000	.880	.000	.917	.990	.997
NEW YORK	.984	.924	.000	.000	.924	.000	.998
NORTH CAROLINA	.961	.903	.885	.000	.890	.985	.994
NORTH DAKOTA	.987	.928	.000	.989	.919	.000	.999
OHIO	.982	.921	.000	.000	.945	.000	.998
OKLAHOMA	.975	.914	.961	.000	.944	.989	.997
OREGON	.992	.000	.000	.993	.950	.000	.999
PENNSYLVANIA	.978	.917	.000	.000	.924	.990	.998
RHODE ISLAND	.964	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	.963	.904	.889	.000	.883	.985	.995
SOUTH DAKOTA	.983	.922	.000	.985	.923	.992	.998
TENNESSEE	.976	.915	.992	.000	.910	.989	.997
TEXAS	.982	.921	.966	.000	.924	.990	.998
UTAH	.965	.000	.000	.972	.886	.000	.995
VERMONT	.981	.000	.000	.000	.000	.000	.000
VIRGINIA	.961	.903	.884	.000	.904	.985	.994
WASHINGTON	.996	.000	.000	.996	.956	.000	.999
WEST VIRGINIA	.980	.000	.000	.000	.930	.000	.998
WISCONSIN	.985	.924	.000	.987	.911	.000	.999
WYOMING	.975	.000	.000	.979	.901	.000	.997

Table D28. Yield Adjustments for Analysis IV:

10% Ozone Reduction

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	1.005	1.026	1.026	.000	1.013	1.004	.000
ARIZONA	1.004	.000	1.042	1.006	1.016	1.004	1.001
ARKANSAS	1.006	1.028	1.031	.000	1.016	1.004	.000
CALIFORNIA	1.005	.000	1.048	1.007	1.015	1.004	1.001
COLORADO	1.005	.000	.000	1.007	1.017	1.004	1.001
CONNECTICUT	1.006	.000	.000	.000	.000	.000	.000
DELAWARE	1.004	1.025	.000	.000	1.009	.000	1.001
FLORIDA	1.002	1.020	1.016	.000	.000	.000	.000
GEORGIA	1.005	1.026	1.037	.000	1.014	1.004	.000
IDAHO	1.005	.000	.000	1.006	1.016	.000	1.001
ILLINOIS	1.004	1.025	.000	.000	1.012	1.003	1.001
INDIANA	1.004	1.025	.000	.000	1.001	1.003	.000
IOWA	1.003	1.021	.000	.000	1.012	1.003	.000
KANSAS	1.003	1.024	.000	.000	1.016	1.003	1.001
KENTUCKY	1.003	1.023	.000	.000	1.011	1.003	1.001
LOUISIANA	1.003	1.021	1.018	.000	1.010	1.003	.000
MAINE	1.002	.000	.000	.000	.000	.000	.000
MARYLAND	1.004	1.026	.000	.000	1.008	.000	1.001
MASSACHUSETTS	1.004	.000	.000	.000	.000	.000	.000
MICHIGAN	1.002	1.020	.000	.000	1.008	.000	1.000
MINNESOTA	1.002	1.094	.000	1.003	1.011	.000	1.000
MISSISSIPPI	1.004	1.026	1.026	.000	1.016	1.004	.000
MISSOURI	1.004	1.025	1.025	.000	1.015	1.004	.000
MONTANA	1.004	.000	.000	1.005	1.011	.000	1.001
NEBRASKA	1.003	1.022	.000	.000	1.013	1.003	1.000
NEVADA	1.005	.000	1.050	1.007	1.013	.000	1.001
NEW HAMPSHIRE	1.002	.000	.000	.000	.000	.000	.000
NEW JERSEY	1.005	1.027	.000	.000	1.010	.000	1.001
NEW MEXICO	1.005	.000	1.044	.000	1.014	1.004	1.001
NEW YORK	1.002	1.021	.000	.000	1.011	.000	1.000
NORTH CAROLINA	1.007	1.028	1.031	.000	1.016	1.004	1.001
NORTH DAKOTA	1.002	1.019	.000	1.003	1.010	.000	1.000
OHIO	1.003	1.023	.000	.000	1.009	.000	1.000
OKLAHOMA	1.005	1.026	1.015	.000	1.011	1.004	1.001
OREGON	1.001	.000	.000	1.002	1.005	.000	1.000
PENNSYLVANIA	1.003	1.022	.000	.000	1.011	1.003	1.000
RHODE ISLAND	1.005	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	1.007	1.029	1.035	.000	1.019	1.005	1.001
SOUTH DAKOTA	1.002	1.020	.000	1.004	1.011	1.002	1.000
TENNESSEE	1.004	1.024	1.023	.000	1.012	1.003	1.001
TEXAS	1.003	1.024	1.013	.000	1.012	1.003	1.001
UTAH	1.006	.000	.000	1.007	1.019	.000	1.001
VERMONT	1.003	.000	.000	.000	.000	.000	.000
VIRGINIA	1.005	1.027	1.030	.000	1.012	1.004	1.001
WASHINGTON	1.001	.000	.000	1.001	1.005	.000	1.000
WEST VIRGINIA	1.003	.000	.000	.000	1.010	.000	1.000
WISCONSIN	1.003	1.022	.000	1.004	1.013	.000	1.000
WYOMING	1.005	.000	.000	1.007	1.017	.000	1.001

Table D29. Yield Adjustments for Analysis IV:

25% Ozone Reduction

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	1.009	1.065	1.059	.000	1.030	1.008	.000
ARIZONA	1.009	.000	1.094	1.013	1.037	1.008	1.001
ARKANSAS	1.011	1.070	1.031	.000	1.037	1.009	.000
CALIFORNIA	1.011	.000	1.048	1.015	1.034	1.009	1.002
COLORADO	1.011	.000	.000	1.016	1.039	1.009	1.002
CONNECTICUT	1.012	.000	.000	.000	.000	.000	.000
DELAWARE	1.008	1.062	.000	.000	1.020	.000	1.001
FLORIDA	1.005	1.050	1.016	.000	.000	.000	.000
GEORGIA	1.009	1.065	1.037	.000	1.032	1.008	.000
IDAHO	1.010	.000	.000	1.014	1.037	.000	1.002
ILLINOIS	1.008	1.062	.000	.000	1.026	1.008	1.001
INDIANA	1.008	1.062	.000	.000	1.021	1.008	.000
IOWA	1.005	1.052	.000	.000	1.026	1.006	.000
KANSAS	1.007	1.059	.000	.000	1.026	1.007	1.001
KENTUCKY	1.007	1.058	.000	.000	1.025	1.007	1.001
LOUISIANA	1.005	1.053	1.018	.000	1.023	1.006	.000
MAINE	1.004	.000	.000	.000	.000	.000	.000
MARYLAND	1.009	1.065	.000	.000	1.018	.000	1.001
MASSACHUSETTS	1.007	.000	.000	.000	.000	.000	.000
MICHIGAN	1.004	1.049	.000	.000	1.018	.000	1.001
MINNESOTA	1.004	1.048	.000	1.007	1.025	.000	1.001
MISSISSIPPI	1.009	1.064	1.026	.000	1.035	1.008	.000
MISSOURI	1.009	1.062	1.025	.000	1.034	1.008	.000
MONTANA	1.008	.000	.000	1.011	1.026	.000	1.001
NEBRASKA	1.006	1.055	.000	.000	1.031	1.006	1.001
NEVADA	1.011	.000	1.050	1.015	1.040	.000	1.002
NEW HAMPSHIRE	1.005	.000	.000	.000	.000	.000	.000
NEW JERSEY	1.010	1.066	.000	.000	1.024	.000	1.002
NEW MEXICO	1.009	.000	1.044	.000	1.032	1.008	1.001
NEW YORK	1.005	1.052	.000	.000	1.026	.000	1.001
NORTH CAROLINA	1.011	1.069	1.069	.000	1.037	1.009	1.002
NORTH DAKOTA	1.004	1.047	.000	1.006	1.023	.000	1.000
OHIO	1.006	1.057	.000	.000	1.021	.000	1.001
OKLAHOMA	1.010	1.066	1.036	.000	1.025	1.008	1.002
OREGON	1.003	.000	.000	1.005	1.012	.000	1.000
PENNSYLVANIA	1.006	1.045	.000	.000	1.025	1.006	1.001
RHODE ISLAND	1.010	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	1.034	1.074	1.079	.000	1.043	1.010	1.002
SOUTH DAKOTA	1.005	1.051	.000	1.007	1.024	1.005	1.001
TENNESSEE	1.008	1.061	1.023	.000	1.028	1.007	1.001
TEXAS	1.007	1.059	1.033	.000	1.027	1.007	1.001
UTAH	1.011	.000	.000	1.016	1.044	.000	1.002
VERMONT	1.005	.000	.000	.000	.000	.000	.000
VIRGINIA	1.011	1.068	1.066	.000	1.026	1.009	1.002
WASHINGTON	1.002	.000	.000	1.003	1.012	.000	1.002
WEST VIRGINIA	1.005	.000	.000	.000	1.023	.000	1.001
WISCONSIN	1.006	1.055	.000	1.009	1.030	.000	1.001
WYOMING	1.010	.000	.000	1.014	1.038	.000	1.002

Table D30. Yield Adjustments for Analysis IV:

40% Ozone Reduction

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	1.012	1.104	1.084	.000	1.043	1.012	.000
ARIZONA	1.012	.000	1.125	1.017	1.053	1.011	1.002
ARKANSAS	1.015	1.112	1.099	.000	1.053	1.014	.000
CALIFORNIA	1.014	.000	1.155	1.020	1.049	1.013	1.002
COLORADO	1.015	.000	.000	1.021	1.057	1.013	1.002
CONNECTICUT	1.016	.000	.000	.000	.000	.000	.000
ARE	1.011	1.098	.000	.000	1.029	.000	1.002	1.035
FLORIDA	1.010	1.080	1.050	.000	.000	.000	.000
GEORGIA	1.012	1.103	1.084	.000	1.046	1.012	.000
IDAHO	1.013	.000	.000	1.019	1.053	.000	1.002
ILLINOIS	1.011	1.099	.000	.000	1.038	1.011	1.002
INDIANA	1.011	1.099	.000	.000	1.030	1.011	.000
IOWA	1.007	1.083	.000	.000	1.038	1.008	.000
KANSAS	1.009	1.094	.000	.000	1.038	1.010	1.001
KENTUCKY	1.009	1.093	.000	.000	1.035	1.010	1.001
LOUISIANA	1.007	1.085	1.055	.000	1.037	1.008	.000
MAINE	1.005	.000	.000	.000	.000	.000	.000
MARYLAND	1.020	1.103	.000	.000	1.026	.000	1.002
MASSACHUSETTS	1.009	.000	.000	.000	.000	.000	.000
MICHIGAN	1.005	1.078	.000	.000	1.027	.000	1.001
MINNESOTA	1.005	1.077	.000	1.009	1.037	.000	1.001
MISSISSIPPI	1.012	1.102	1.082	.000	1.051	1.012	.000
MISSOURI	1.012	1.099	1.078	.000	1.049	1.011	.000
MONTANA	1.010	.000	.000	1.015	1.037	.000	1.001
NEBRASKA	1.008	1.088	.000	.000	1.044	1.009	1.001
NEVADA	1.014	.000	1.161	1.021	1.058	.000	1.002
NEW HAMPSHIRE	1.006	.000	.000	.000	.000	.000	.000
NEW JERSEY	1.013	1.106	.000	.000	1.034	.000	1.002
NEW MEXICO	1.012	.000	1.141	.000	1.047	1.012	1.002
NEW YORK	1.006	1.082	.000	.000	1.037	.000	1.001
NORTH CAROLINA	1.015	1.110	1.098	.000	1.053	1.013	1.002
NORTH DAKOTA	1.005	1.074	.000	1.008	1.033	.000	1.001
OHIO	1.008	1.090	.000	.000	1.031	.000	1.001
OKLAHOMA	1.012	1.105	1.057	.000	1.036	1.012	1.002
OREGON	1.003	.000	.000	1.006	1.017	.000	1.000
PENNSYLVANIA	1.007	1.087	.000	.000	1.036	1.009	1.001
RHODE ISLAND	1.014	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	1.018	1.118	1.112	.000	1.062	1.015	1.003
SOUTH DAKOTA	1.006	1.080	.000	1.010	1.034	1.008	1.001
TENNESSEE	1.010	1.096	1.073	.000	1.041	1.011	1.001
TEXAS	1.009	1.095	1.051	.000	1.040	1.010	1.001
UTAH	1.015	.000	.000	1.022	1.064	.000	1.002
VERMONT	1.007	.000	.000	.000	.000	.000	.000
VIRGINIA	1.014	1.109	1.094	.000	1.038	1.013	1.002
WASHINGTON	1.002	.000	.000	1.004	1.017	.000	1.002
WEST VIRGINIA	1.007	.000	.000	.000	1.033	.000	1.001
WISCONSIN	1.008	1.087	.000	1.012	1.043	.000	1.001
WYOMING	1.013	.000	.000	1.019	1.055	.000	1.002

Table D31. Yield Adjustments for Analysis IV:

25% Ozone Increase

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	.983	.936	.918	.000	.961	.989	.000
ARIZONA	.983	.000	.873	.980	.952	.989	.997
ARKANSAS	.979	.931	.905	.000	.952	.988	.000
CALIFORNIA	.980	.000	.856	.977	.956	.988	.996
COLORADO	.979	.000	.000	.976	.949	.987	.996
CONNECTICUT	.977	.000	.000	.000	.000	.000	.000
DELAWARE	.984	.939	.000	.000	.973	.000	.997
FLORIDA	.991	.949	.950	.000	.000	.000	.000
GEORGIA	.983	.936	.918	.000	.958	.989	.000
IDAHO	.982	.000	.000	.980	.952	.000	.997
ILLINOIS	.984	.938	.000	.000	.965	.989	.997
INDIANA	.985	.939	.000	.000	.973	.990	.000
IOWA	.990	.948	.000	.000	.965	.993	.000
KANSAS	.987	.941	.000	.000	.965	.991	.998
KENTUCKY	.987	.942	.000	.000	.968	.991	.998
LOUISIANA	.990	.947	.945	.000	.969	.990	.000
MAINE	.993	.000	.000	.000	.000	.000	.000
MARYLAND	.983	.936	.000	.000	.976	.000	.997
MASSACHUSETTS	.986	.000	.000	.000	.000	.000	.000
MICHIGAN	.992	.951	.000	.000	.976	.000	.999
MINNESOTA	.992	.952	.000	.989	.966	.000	.999
MISSISSIPPI	.983	.937	.921	.000	.954	.989	.000
MISSOURI	.984	.939	.924	.000	.956	.990	.000
MONTANA	.986	.000	.000	.983	.966	.000	.998
NEBRASKA	.988	.945	.000	.000	.960	.992	.998
NEVADA	.979	.000	.851	.976	.948	.000	.996
NEW HAMPSHIRE	.991	.000	.000	.000	.000	.000	.000
NEW JERSEY	.981	.934	.000	.000	.969	.000	.997
NEW MEXICO	.982	.000	.867	.000	.958	.990	.997
NEW YORK	.991	.948	.000	.000	.966	.000	.999
NORTH CAROLINA	.979	.932	.906	.000	.952	.988	.996
NORTH DAKOTA	.993	.953	.000	.990	.969	.000	.999
OHIO	.988	.944	.000	.000	.972	.000	.998
OKLAHOMA	.982	.935	.960	.000	.967	.989	.997
OREGON	.995	.000	.000	.993	.985	.000	.999
PENNSYLVANIA	.989	.946	.000	.000	.967	.992	.998
RHODE ISLAND	.981	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	.975	.928	.896	.000	.945	.986	.995
SOUTH DAKOTA	.991	.949	.000	.988	.969	.993	.999
TENNESSEE	.985	.939	.926	.000	.963	.990	.997
TEXAS	.987	.941	.965	.000	.964	.991	.998
UTAH	.979	.000	.000	.975	.943	.000	.996
VERMONT	.990	.000	.000	.000	.000	.000	.000
VIRGINIA	.980	.933	.910	.000	.966	.988	.996
WASHINGTON	.997	.000	.000	.995	.984	.000	.999
WEST VIRGINIA	.990	.000	.000	.000	.970	.000	.998
WISCONSIN	.989	.945	.000	.986	.961	.000	.998
WYOMING	.981	.000	.000	.978	.951	.000	.997

Table D32. Yield Adjustments for Analysis V:

10% Ozone Reduction

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	1.003	1.017	1.017	.000	1.010	1.003	.000
ARIZONA	1.006	.000	1.017	1.008	1.015	1.004	1.001
ARKANSAS	1.004	1.020	1.024	.000	1.010	1.003	.000
CALIFORNIA	1.006	.000	1.018	1.008	1.014	1.004	1.001
COLORADO	1.006	.000	.000	1.008	1.016	1.004	1.001
CONNECTICUT	1.010	.000	.000	.000	.000	.000	.000
DELAWARE	1.002	1.019	.000	.000	1.012	.000	1.000
FLORIDA	1.002	1.013	1.009	.000	.000	.000	.000
GEORGIA	1.002	1.016	1.016	.000	1.009	1.002	.000
IDAHO	1.004	.000	.000	1.006	1.017	.000	1.001
ILLINOIS	1.003	1.019	.000	.000	1.009	1.003	1.001
INDIANA	1.004	1.023	.000	.000	1.007	1.004	.000
IOWA	1.002	1.015	.000	.000	1.008	1.002	.000
KANSAS	1.003	1.019	.000	.000	1.009	1.002	1.001
KENTUCKY	1.003	1.017	.000	.000	1.008	1.002	1.001
LOUISIANA	1.003	1.023	1.014	.000	1.009	1.003	.000
MAINE	1.002	.000	.000	.000	.000	.000	.000
MARYLAND	1.004	1.020	.000	.000	1.009	.000	1.007
MASSACHUSETTS	1.003	.000	.000	.000	.000	.000	.000
MICHIGAN	1.002	1.020	.000	.000	1.008	.000	1.000
MINNESOTA	1.001	1.015	.000	1.003	1.009	.000	1.000
MISSISSIPPI	1.004	1.019	1.020	.000	1.112	1.003	.000
MISSOURI	1.003	1.018	1.020	.000	1.010	1.003	.000
MONTANA	1.004	.000	.000	1.005	1.013	.000	1.001
NEBRASKA	1.003	1.019	.000	.000	1.010	1.002	1.001
NEVADA	1.006	.000	1.017	1.008	1.015	.000	1.001
NEW HAMPSHIRE	1.002	.000	.000	.000	.000	.000	.000
NEW JERSEY	1.005	1.020	.000	.000	1.009	.000	1.001
NEW MEXICO	1.004	.000	1.014	.000	1.041	1.003	1.001
NEW YORK	1.002	1.018	.000	.000	1.009	.000	1.000
NORTH CAROLINA	1.005	1.021	1.025	.000	1.011	1.003	1.007
NORTH DAKOTA	1.002	1.015	.000	1.002	1.010	.000	1.000
OHIO	1.003	1.023	.000	.000	1.009	.000	1.000
OKLAHOMA	1.003	1.018	1.010	.000	1.008	1.003	1.001
OREGON	1.001	.000	.000	1.002	1.006	.000	1.000
PENNSYLVANIA	1.004	1.024	.000	.000	1.011	1.003	1.001
RHODE ISLAND	1.007	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	1.005	1.022	1.027	.000	1.015	1.004	1.001
SOUTH DAKOTA	1.002	1.017	.000	1.003	1.009	1.002	1.000
TENNESSEE	1.003	1.020	1.020	.000	1.012	1.003	1.001
TEXAS	1.002	1.015	1.009	.000	1.009	1.002	1.000
UTAH	1.007	.000	.000	1.008	1.020	.000	1.001
VERMONT	1.003	.000	.000	.000	.000	.000	.000
VIRGINIA	1.007	1.031	1.038	.000	1.016	1.005	1.001
WASHINGTON	1.001	.000	.000	1.001	1.005	.000	1.000
WEST VIRGINIA	1.003	.000	.000	.000	1.010	.000	1.001
WISCONSIN	1.002	1.015	.000	1.003	1.010	.000	1.000
WYOMING	1.005	.000	.000	1.006	1.017	.000	1.001

Table D33. Yield Adjustments for Analysis V:

25% Ozone Reduction

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	1.006	1.042	1.037	.000	1.022	1.005	.000
ARIZONA	1.012	.000	1.123	1.017	1.033	1.010	1.002
ARKANSAS	1.008	1.049	1.050	.000	1.023	1.007	.000
CALIFORNIA	1.013	.000	1.126	1.017	1.032	1.010	1.002
COLORADO	1.012	.000	.000	1.016	1.037	1.010	1.002
CONNECTICUT	1.012	.000	.000	.000	.000	.000	.000
DELAWARE	1.003	1.046	.000	.000	1.027	.000	1.000
FLORIDA	1.002	1.033	1.020	.000	.000	.000	.000
GEORGIA	1.006	1.040	1.034	.000	1.021	1.005	.000
IDAHO	1.008	.000	.000	1.012	1.038	.000	1.001
ILLINOIS	1.007	1.046	.000	.000	1.021	1.006	1.001
INDIANA	1.008	1.056	.000	.000	1.016	1.007	.000
IOWA	1.004	1.039	.000	.000	1.020	1.004	.000
KANSAS	1.006	1.048	.000	.000	1.019	1.005	1.001
KENTUCKY	1.006	1.044	.000	.000	1.018	1.005	1.001
LOUISIANA	1.006	1.056	1.043	.000	1.020	1.006	.000
MAINE	1.003	.000	.000	.000	.000	.000	.000
MARYLAND	1.007	1.050	.000	.000	1.020	.000	1.002
MASSACHUSETTS	1.007	.000	.000	.000	.000	.000	.000
MICHIGAN	1.004	1.049	.000	.000	1.019	.000	1.001
MINNESOTA	1.004	1.037	.000	1.006	1.019	.000	1.001
MISSISSIPPI	1.007	1.048	1.046	.000	1.026	1.006	.000
MISSOURI	1.007	1.046	1.044	.000	1.026	1.006	.000
MONTANA	1.008	.000	.000	1.011	1.038	.000	1.001
NEBRASKA	1.006	1.046	.000	.000	1.022	1.005	1.001
NEVADA	1.012	.000	1.118	1.016	1.033	.000	1.002
NEW HAMPSHIRE	1.005	.000	.000	.000	.000	.000	.000
NEW JERSEY	1.010	1.052	.000	.000	1.020	.000	1.001
NEW MEXICO	1.008	.000	1.089	.000	1.029	1.008	1.001
NEW YORK	1.004	1.043	.000	.000	1.020	.000	1.001
NORTH CAROLINA	1.010	1.052	1.057	.000	1.029	1.007	1.002
NORTH DAKOTA	1.003	1.037	.000	1.005	1.021	.000	1.001
OHIO	1.006	1.057	.000	.000	1.016	.000	1.001
OKLAHOMA	1.006	1.045	1.023	.000	1.012	1.006	1.001
OREGON	1.002	.000	.000	1.004	1.014	.000	1.000
PENNSYLVANIA	1.008	1.061	.000	.000	1.026	1.007	1.001
RHODE ISLAND	1.014	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	1.010	1.056	1.061	.000	1.036	1.008	1.002
SOUTH DAKOTA	1.005	1.044	.000	1.007	1.020	1.005	1.001
TENNESSEE	1.007	1.051	1.045	.000	1.026	1.006	1.001
TEXAS	1.004	1.038	1.021	.000	1.017	1.005	1.001
UTAH	1.013	.000	.000	1.018	1.047	.000	1.002
VERMONT	1.007	.000	.000	.000	.000	.000	.000
VIRGINIA	1.015	1.078	1.086	.000	1.036	1.011	1.003
WASHINGTON	1.001	.000	.000	1.002	1.012	.000	1.000
WEST VIRGINIA	1.007	.000	.000	.000	1.023	.000	1.001
WISCONSIN	1.006	1.037	.000	1.006	1.030	.000	1.001
WYOMING	1.009	.000	.000	1.013	1.038	.000	1.001

Table D34. Yield Adjustments for Analysis V:

40% Ozone Reduction

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	1.008	1.068	1.053	.000	1.033	1.008	.000
ARIZONA	1.012	.000	1.130	1.023	1.048	1.014	1.002
ARKANSAS	1.011	1.078	1.071	.000	1.034	1.010	.000
CALIFORNIA	1.016	.000	1.179	1.024	1.046	1.015	1.003
COLORADO	1.015	.000	.000	1.022	1.054	1.014	1.002
CONNECTICUT	1.025	.000	.000	.000	.000	.000	.000
DELAWARE	1.005	1.073	.000	.000	1.040	.000	1.001
FLORIDA	1.003	1.053	1.028	.000	.000	.000	.000
GEORGIA	1.007	1.062	1.049	.000	1.031	1.007	.000
IDAHO	1.010	.000	.000	1.016	1.055	.000	1.001
ILLINOIS	1.008	1.073	.000	.000	1.030	1.009	1.001
INDIANA	1.010	1.089	.000	.000	1.023	1.010	.000
IOWA	1.007	1.062	.000	.000	1.028	1.006	.000
KANSAS	1.008	1.076	.000	.000	1.027	1.009	1.001
KENTUCKY	1.007	1.070	.000	.000	1.026	1.007	1.001
LOUISIANA	1.010	1.089	1.061	.000	1.029	1.009	.000
MAINE	1.004	.000	.000	.000	.000	.000	.000
MARYLAND	1.010	1.079	.000	.000	1.029	.000	1.002
MASSACHUSETTS	1.008	.000	.000	.000	.000	.000	.000
MICHIGAN	1.005	1.077	.000	.000	1.027	.000	1.001
MINNESOTA	1.004	1.006	.000	1.007	1.027	.000	1.001
MISSISSIPPI	1.010	1.076	1.064	.000	1.038	1.009	.000
MISSOURI	1.010	1.074	1.063	.000	1.037	1.009	.000
MONTANA	1.010	.000	.000	1.015	1.054	.000	1.001
NEBRASKA	1.008	1.074	.000	.000	1.032	1.008	1.001
NEVADA	1.015	.000	1.168	1.022	1.048	.000	1.002
NEW HAMPSHIRE	1.006	.000	.000	.000	.000	.000	.000
NEW JERSEY	1.012	1.082	.000	.000	1.029	.000	1.002
NEW MEXICO	1.011	.000	1.126	.000	1.042	1.011	1.002
NEW YORK	1.006	1.069	.000	.000	1.029	.000	1.001
NORTH CAROLINA	1.013	1.082	1.081	.000	1.042	1.011	1.002
NORTH DAKOTA	1.007	1.058	.000	1.001	1.030	.000	1.001
OHIO	1.008	1.091	.000	.000	1.024	.000	1.001
OKLAHOMA	1.008	1.072	1.039	.000	1.017	1.008	1.001
OREGON	1.003	.000	.000	1.001	1.020	.000	1.000
PENNSYLVANIA	1.010	1.097	.000	.000	1.037	1.011	1.001
RHODE ISLAND	1.018	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	1.014	1.089	1.086	.000	1.052	1.012	1.002
SOUTH DAKOTA	1.008	1.069	.000	1.010	1.030	1.007	1.001
TENNESSEE	1.009	1.082	1.064	.000	1.038	1.009	1.002
TEXAS	1.005	1.060	1.032	.000	1.025	1.006	1.001
UTAH	1.018	.000	.000	1.025	1.068	.000	1.003
VERMONT	1.090	.000	.000	.000	.000	.000	.000
VIRGINIA	1.020	1.125	1.123	.000	1.052	1.016	1.003
WASHINGTON	1.002	.000	.000	1.000	1.017	.000	1.000
WEST VIRGINIA	1.009	.000	.000	.000	1.033	.000	1.001
WISCONSIN	1.005	1.059	.000	1.008	1.032	.000	1.001
WYOMING	1.012	.000	.000	1.018	1.055	.000	1.002

Table D35. Yield Adjustments for Analysis V:

25% Ozone Increase

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	.990	.958	.947	.000	.971	.993	.000
ARIZONA	.977	.000	.840	.974	.957	.967	.996
ARKANSAS	.984	.952	.933	.000	.969	.978	.000
CALIFORNIA	.976	.000	.837	.973	.958	.987	.996
COLORADO	.978	.000	.000	.975	.951	.987	.996
CONNECTICUT	.964	.000	.000	.000	.000	.000	.000
DELAWARE	.994	.954	.000	.000	.964	.000	.999
FLORIDA	.996	.974	.971	.000	.000	.000	.000
GEORGIA	.960	.962	.952	.000	.973	.993	.000
IDAHO	.985	.000	.000	.981	.951	.000	.997
ILLINOIS	.988	.955	.000	.000	.973	.992	.998
INDIANA	.986	.945	.000	.000	.979	.990	.000
IOWA	.992	.961	.000	.000	.975	.994	.000
KANSAS	.985	.953	.000	.000	.975	.992	.999
KENTUCKY	.990	.957	.000	.000	.976	.993	.999
LOUISIANA	.989	.944	.939	.000	.973	.992	.000
MAINE	.994	.000	.000	.000	.000	.000	.000
MARYLAND	.986	.951	.000	.000	.973	.000	.998
MASSACHUSETTS	.988	.000	.000	.000	.000	.000	.000
MICHIGAN	.993	.951	.000	.000	.975	.000	.999
MINNESOTA	.994	.963	.000	.991	.975	.000	.999
MISSISSIPPI	.986	.953	.938	.000	.966	.992	.000
MISSOURI	.986	.985	.940	.000	.967	.992	.000
MONTANA	.986	.000	.000	.982	.951	.000	.998
NEBRASKA	.989	.954	.000	.000	.970	.992	.999
NEVADA	.978	.000	.846	.975	.957	.000	.996
NEW HAMPSHIRE	.991	.000	.000	.000	.000	.000	.000
NEW JERSEY	.982	.950	.000	.000	.974	.000	.997
NEW MEXICO	.985	.000	.880	.000	.962	.990	.997
NEW YORK	.991	.957	.000	.000	.974	.000	.998
NORTH CAROLINA	.982	.950	.924	.000	.962	.990	.996
NORTH DAKOTA	.994	.964	.000	.992	.973	.000	.993
OHIO	.988	.943	.000	.000	.978	.000	.998
OKLAHOMA	.988	.956	.973	.000	.985	.992	.998
OREGON	.996	.000	.000	.993	.981	.000	.999
PENNSYLVANIA	.986	.939	.000	.000	.966	.990	.998
RHODE ISLAND	.978	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	.980	.945	.919	.000	.954	.989	.996
SOUTH DAKOTA	.991	.956	.000	.988	.973	.994	.998
TENNESSEE	.987	.950	.938	.000	.966	.991	.998
TEXAS	.992	.966	.978	.000	.978	.993	.999
UTAH	.975	.000	.000	.972	.940	.000	.995
VERMONT	.988	.000	.000	.000	.000	.000	.000
VIRGINIA	.972	.924	.884	.000	.953	.985	.994
WASHINGTON	.998	.000	.000	.996	.984	.000	.999
WEST VIRGINIA	.987	.000	.000	.000	.969	.000	.998
WISCONSIN	.986	.963	.000	.991	.970	.000	.999
WYOMING	.983	.000	.000	.979	.951	.000	.997

*GPO 593-975 1984